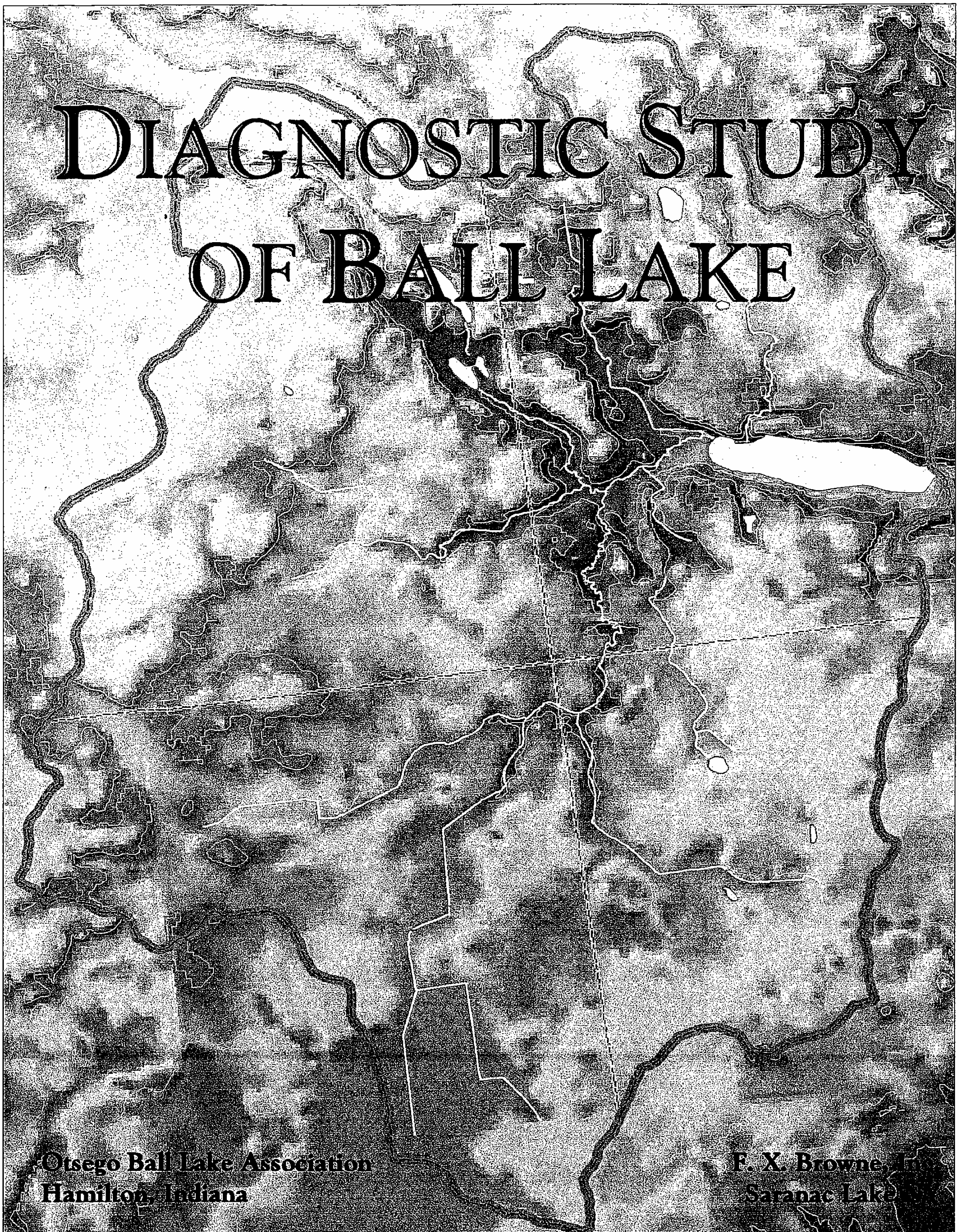
DIAGNOSTIC STUDY OF BALL LAKE



Otsego Ball Lake Association
Hamilton, Indiana

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Saranac Lake

Diagnostic Study of Ball Lake

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Presented to:
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EXECUTIVE SUMMARY

BACKGROUND

The Ball Lake Preliminary Diagnostic Study was undertaken by the Otsego Ball Lake Association under the Indiana Lake and River Enhancement Program (LARE) due to concerns over declining water quality. Water quality has been declining in Ball Lake since at least the mid-1960s. The IDEM Eutrophication Index has generally increased over that time period and oxygen concentrations have declined in the bottom waters during summer stratification. The project was initiated in the Fall of 2000 and conducted throughout 2001 by F. X. Browne, Inc. The purpose of this project was to describe conditions and trends in the lake and subwatersheds, identify potential nonpoint source water quality problems, develop a plan for future work to address identified water quality issues, and predict and assess success factors for future work.

THE LAKE

Ball Lake has a relatively densely developed shoreline consisting primarily of year-round homes served by municipal water or wells and municipal sewers. Boating activity is generally light, although the lake is a popular fishing destination. Despite problems with an unbalanced fishery, Ball Lake is still considered one of the better fishing opportunities in northeastern Indiana for trophy largemouth bass and is also a destination for tiger muskie and panfish fishing. In 1983, IDNR Fisheries noted that, on per acre basis, Ball Lake supported one of the largest largemouth bass populations of any northern Indiana lake (Ledet 1983).

Ball Lake has a court-established regulated water level of 894.76 feet above MSL and a high water level of 899.91 feet above MSL. The lake is long, narrow and deep, with a surface area of 343,028 m^2 (84.76 ac), a maximum depth of 19.5 m (64 ft), a mean depth of 12.2 m (40 ft), and a lake volume of 4,181,820 m^3 (147.7 million ft^3). No areas of significant erosion were observed along the shores of Ball Lake. The shoreline of Ball Lake has few bulkheads and only about 50 percent of the shore has some sort of armoring installed. Most of this armoring distracts very little from the natural look of the Ball Lake shore, being primarily areas of placed stone/round rock at the waterline or low horizontal wood walls or logs.

THE WATERSHED

The 7,609 acre Ball Lake watershed is bisected north and south by the county line between Steuben County to the north and DeKalb County to the south. The watershed is cut into approximate quarters by the towns of Steuben to the NW and Otsego to the NE in Steuben County and Smithfield to the SW and Franklin to the SE in DeKalb County.

The Ball Lake watershed is characterized by gentle rolling topography, with steeper slopes and ravine areas near the tributaries. Numerous wetlands and water features provide exceptional wildlife habitat, as does the watersheds fields and forests. As a result, the watershed offers some excellent opportunities to observe its unique landforms and its habitat and wildlife diversity.

Land use in the Ball Lake watershed is predominantly agricultural (nearly 80 percent), with 65.5 percent of the watershed in row crops and 14.2 percent of the watershed in pasture and hay. Deciduous forest cover accounted for 15.1 percent of the watershed area. Open water and wetlands account for 5 percent of the watershed area. The watershed contains 11.5 miles of dirt/gravel roads, 13.5 miles of paved roads, and 3.4 miles of railroad. The watershed is sparsely populated, with the majority of homes located around Ball Lake, and the remaining watershed consisting primarily of farm properties.

Major water quality problem areas within the watershed are generally associated with the streams and streambanks. Much of the soils in the watershed are highly erosive, and while land use/agricultural practices have helped minimize erosion on the uplands, the streams themselves cut deeply into these soils. Consequently, significant amounts of erosion occurs along the stream banks during periods of high flow.

Water Quality

In 2001, Ball Lake was mesotrophic to eutrophic depending on the metrics used. The IDEM Eutrophication Index was 55, in the eutrophic range, primarily due to the presence of a bloom of the bloom-green bacteria, *Cylindrospermopsis*, in the phytoplankton. As a result, Carlson TSIs for chlorophyll *a* and transparency were also in the eutrophic range, while the phosphorus TSI was in the mesotrophic range. There was essentially no dissolved oxygen in the lake below a depth of about 4 meters (11 ft).

The main tributaries to Ball Lake were only slightly to moderately impacted based upon macroinvertebrate and habitat assessments. Phosphorus concentrations in the streams were generally moderate to high under both wet weather and baseflow conditions. Fecal coliform bacteria numbers were elevated in the wet weather samples.

Sediment thickness in Ball Lake generally ranged from 5 to 11 feet, with the deepest sediments having accumulated in the middle of the lake its deepest point. A sand and gravel bar is present at the main inlet of the lake, coming to within a few inches of the lake surface. A smaller sand and gravel bar is present at the mouth of a smaller inlet on the northwest shore of the lake.

Ball Lake had a typical assemblage of aquatic plants, with the exception of the presence of the invasive species Eurasian watermilfoil in the lake and purple loosestrife along the shore. Within Ball Lake, Eurasian watermilfoil, and aquatic plants in general, were limited by the steeply sloping bathymetry around the lake shore. Water depth drops off rapidly except at inlet and outlet ends, so Eurasian watermilfoil was primarily limited to broad beds in those regions and a narrow band along the north and south shore. Unfortunately, it is nearly impossible to get a boat from shore or the launch out into the main lake without passing through the Eurasian watermilfoil stands. Purple loosestrife was limited to several apparently cultivated plantings along the southern shore of the lake.

Nonpoint Source Problem Areas

The major sources of erosion and nonpoint source pollution problem areas in the Ball Lake watershed appear to be eroding streambanks and roadside erosion. Ditching and tiling of farm fields has allowed the farm fields and other areas to drain faster during storm events, thereby increasing the volume and peak discharge of stormwater runoff in the natural streams that drain to Ball Lake. Due to the highly erodible soils in the watershed, there are many areas of severely eroded streambanks from the high peak flows that occur during larger rain events.

Management Recommendations

General Issues

Since the Ball Lake watershed contains a diversity of valuable habitat, habitat surveys would have to be conducted prior to initiating any project that may potentially impact suitable habitat for rare, threatened or endangered species. This would include surveys of forest habitats for the presence of the Indiana bat, stream habitats for the presence of the three mussel species (white cat's paw pearly, clubshell, and northern riffleshell) and any fish population, and wetland habitats for the presence of the northern copperbelly water snake.

In-Lake Management Recommendations

Recommendation One - maintain/improve on naturalized shoreline

Ball Lake is fairly unique in that its shoreline has not been lined with bulkheads and there are still many areas with relatively natural shoreline. Lakeshore residents should be encouraged to use naturalized and bio-engineered solutions where shoreline erosion becomes a problem. A vegetated buffer of low-growing native plants and shrubs along the shore will filter shoreline runoff, providing water quality benefits to the lake and improving the aesthetics of the shore. Native aquatic plants should be allowed to grow in the water along the shore's edge.

Recommendation Two - Control of Invasive Plants

Eurasian watermilfoil does not appear to need controlling at this time. Benthic mats are suggested for creating boating access lanes if it becomes too difficult to get a boat from shore out into the deeper parts of the lake. Signs should be created and placed at public access points that serve to educate lake visitors so that Eurasian watermilfoil is not spread to other waterways.

Purple loosestrife (Lythrum salicaria) needs to be eliminated from the shores of Ball Lake before it infests the valuable wetlands of the watershed.

Recommendation Three - Hypolimnetic Oxygenation

A feasibility study should be initiated for restoring the oxygen to the hypolimnion of Ball Lake. This would serve to eliminate internal recycling of phosphorus while restoring habitat for the restoration of a coldwater fishery in the lake. It is recommended that an oxygen system rather than an aeration system be considered for Ball Lake due to its much lower capital cost and lower operational and maintenance costs. In addition, an oxygenation system designed to use compressed oxygen has a smaller facility requirement and is essentially noise-free, which are important considerations on a developed residential lake such as Ball Lake.

Watershed Management Recommendations

Recommendation One - Pesticide/Herbicide Screening in Tributaries

Streams in the Ball Lake watershed should be sampled for pesticide/herbicide screening to determine whether or not a pesticide/herbicide pollution problem exists within the watershed.

Recommendation Two - Land Stewardship

Agricultural Best Management Practices

Maintain CRP enrollment

CRP enrollments within the Ball Lake watershed will begin expiring over the next few years, resulting in increased row-cropping and runoff of soil and nutrients. The NRCS and County SWCDs should work with the farmers to re-enroll these acres in CRP or some other program that will continue to provide the water quality benefits of continuous cover. This is a key agricultural BMP that will undoubtedly provide the most benefit to the future water quality of Ball Lake.

Increase Use of Buffers

Vegetated buffers along stream and ditch channels serve to filter out sediments and nutrients in overland runoff. County agencies should work with the farmers to institute 25 foot grassed buffers measured from the top of bank along all waterways in the watershed. Additionally, an evaluation of tile inlets should be conducted to assess the use of vegetative buffers around these facilities. SWCDs should work with the farmers to ensure a good buffer around all tile inlets.

Maintain Vegetation in Ditches

A number of the ditches in the Ball Lake watershed are heavily vegetated. Although the tendency is to clean out the ditches to increase water flow, the ditches are deep and contain ample volume. The vegetation present in these ditches is providing nutrient and sediment removal and these benefits should be maintained and encouraged.

Construction Site Erosion and Sedimentation Pollution Control

Nonpoint source pollution from site development, including the construction of individual new homes, may be very significant during earthmoving and construction activities. The potential for soil erosion is very high until the site is stabilized with permanent vegetative cover, and is further heightened when soils are "highly erodible" and on steep slopes. Erosion and sedimentation pollution control plans should be prepared and implemented for all construction activities in the Ball Lake watershed. The Steuben County SWCD and the DeKalb County SWCD should require erosion and sediment control practices for all construction activities in the watershed, and they should inspect all new construction sites to ensure compliance.

Dirt and Gravel Road Maintenance

Sediments washing from dirt and gravel roads are a significant source of nonpoint source pollution in rural areas such as the Ball Lake watershed. The dirt and gravel roads in the Ball Lake watershed should be properly maintained so that sediment does not enter waterways. Roads should be graded and the road edges well vegetated. Properly sized culverts at stream crossings and under driveways and cross streets are imperative, as well as adequate roadside drainage structures.

The Steuben and DeKalb County SWCDs should evaluate Pennsylvania's Dirt and Gravel Road Pollution Prevention Program to determine if it could benefit the Ball Lake watershed.

Shallow concrete basins should be installed along dirt roads where shallow ditches convey sand and gravel into streams and waterways to allow for easy maintenance and removal of sediment from these shallow roadside ditches without having to dig out and disturb the ditch bottom.

Inlet and outlet protection should be provided for all culverts in the watershed, particularly since the majority of the soils are highly erodible. Specifically, the culvert at Station 2 (700 South Road) showed signs outlet scour and water traveling along the outside of the pipe. Inlet and outlet protection was not observed at any of the culverts observed in the watershed during sampling or field investigation. Although each individual culvert was not investigated, a dry culvert along County Line Road was noted to show considerable downstream scour and erosion. Therefore, all road culverts showing signs of erosion should have inlet and outlet protection.

Recommendation Three - Streambank Restoration

Several of the streams and ditches flowing into Ball Lake have eroded streambanks and lack adequate vegetation. Eroded streambank areas were observed all along Myers Ditch, Cameron Ditch, and unnamed ditches in the watershed. Streambank stabilization measures need to be designed and constructed for eroding streambanks in the watershed. It is recommended that measures be implemented at sites closest to the lake initially and then the work should be expanded out into the upper reaches of the watershed.

Rock check dams can be installed in the upstream ditches to reduce stormwater runoff peaks, which will reduce streambank erosion downstream.

Recommendation Four - Wetland Creation

Wetlands are valuable for a number of reasons. In addition to many other benefits, wetland systems provide a low-cost, yet highly effective method of treating stormwater runoff from urban and agricultural areas. Wetland enhancement systems that are constructed in the landscape are carefully designed to meet the specific requirements for the type of stormwater runoff they will treat. Pollutants which threaten the water quality of Ball Lake would be effectively removed within these systems through settling, filtration and biological treatment processes.

Three sites were identified as possible locations for created wetland sites. The first site is located on Myers Ditch at one of three possible locations (at the intersection of 800S (County Line Road) or upstream or downstream of the intersection of the railroad tracks). The second site is located on Cameron Ditch on the upstream side of 100E, and the third site is located on the Cameron Ditch on the upstream side of Boat Launch Road. Wetland creation projects have a high priority since the can effectively filter out sediments and nutrients from stormwater runoff and also help to improve the natural habitat. A feasibility study should be initiated to determine if these sites can be converted to constructed wetlands.

Recommendation Five - Invasive Species Control

Establish Watershed Invasive Species Task Force

An invasive species task force should be established to patrol the watershed for a number of potential invasive plant threats to the watershed's excellent biodiversity.

Control of Purple Loosestrife

Since mechanical and chemical control methods have only limited success and smaller infestations are more likely to be controllable, early diagnosis is critical. Potential loosestrife habitat should be searched annually during late July and August for the plant. Any infestations should be dealt with using appropriate control methodologies. These methods are outlined in detail in the Management Plan recommendations Section.

Fisheries Management Recommendations

IDNR should continue to manage the fishery of Ball Lake, since this is a public resource. Reclamation of the lake would be a necessary step to eliminate the gizzard shad. Reclamation is not a recommendation of this study but mentioned here since there are several concerns that must be addressed prior to initiating this activity, should it be proposed in the future.

INTRODUCTION

PROJECT OBJECTIVES

The Ball Lake Preliminary Diagnostic Study was initiated in the Fall of 2000 by the Otsego Ball Lake Association under Indiana's Lake and River Enhancement Program. The purpose of this project was to describe conditions and trends in the lake and subwatersheds, identify potential nonpoint source water quality problems, develop a plan for future work to address identified water quality issues, and predict and assess success factors for future work.

Water quality in Ball Lake has been declining for many years, based on both anecdotal and limited available historical water quality data. Presently, perceived water quality issues from lake owners includes an unbalanced fish population (overabundance of gizzard shad), weeds, sediment, and color.

The scope of the project was developed based upon a Request for Proposals circulated by the Otsego Ball Lake Association and through refinements of the scope based on discussions with IDNR LARE program staff.

LAKE HISTORY AND USAGE

CREATION OF BALL LAKE

Although most references to Ball Lake in existing reports refer to the lake as a natural water body, it is believed that Ball Lake is a manmade water body, created in the 1800s by surface extraction mining using a dragline (K. Shank, pers. comm. 2001). It is not known for certain what material or mineral was being extracted.

WATER QUALITY TRENDS

Some of the historical water quality information regarding Ball Lake comes from various fisheries studies conducted at irregular intervals by IDNR Division of Fish & Wildlife, Fisheries Section since 1967. These studies were often conducted early in the summer or in late fall and the only water quality information is pH at the surface and bottom, Secchi transparency, and dissolved oxygen and temperature profiles. Though not conducted at the ideal time for water quality assessment, these data do provide some reference for water quality trends in Ball Lake over the past 30 years or more.

Based upon the IDNR fisheries studies, Secchi disk transparency in Ball Lake declined from over three meters (10 feet) in the period between1967 and 1970 to about 1.5 meters (5 feet) in the mid-1980s. Transparency generally remained between 1.5 and 2 meters through the mid-1990s. Transparency in 2001 was 1.1 meters.

Based upon the IDNR fisheries studies, Ball Lake experienced a loss of dissolved oxygen in the bottom waters during the growing season as early as 1967. In August 1967, dissolved oxygen fell to 1.8 mg/L at a depth of 7.6 meters (25 feet). Samples collected in late June 1972 and early July 1975 did not identify as significant a loss of oxygen, probably since the summer lake stratification had not persisted long enough prior to the sampling date for oxygen reduction to occur. In September 1983, the dissolved oxygen concentration fell to 1.5 mg/L at 7.6 meters (25 feet) and in August 1986, the dissolved oxygen concentration dropped to less than 1.0 mg/L starting at a depth of 4.6 m (15 feet). The remaining studies were conducted in early July (1987, 1988, 1996) and generally show that oxygen was beginning to be reduced in the bottom waters as summer stratification progressed. These data suggest that Ball Lake has historically had low oxygen in its bottom waters, but that the degree of anoxia has increased over the period of record.

The IDEM have collected more complete water quality data as part of their Clean Lakes Program. Water quality surveys were conducted at Ball Lake in 1975, 1989, 1992, and 1997. These surveys are summarized together with the corresponding 2001 results in Table 1.1. Based on these measurements, water quality in Ball Lake has generally declined over the past 25 years, particularly as exhibited by an increasing Eutrophication Index and a reduction in the percentage of the water column that is oxygenated during the summer. Phosphorus and nitrogen concentrations were considerably improved in 2001 after having reached peak declines in either 1992 or 1997. Transparency was also better in 2001 than in 1997.

Table 1.1
Historical Water Quality Conditions at Ball Lake

Parameter	1975	1989	1992	1997	2001
Eutrophic Index	34	24	21	46	55
Mean TP (mg/L)	0.040	0.180	0.111	0.260	0.071
Mean SRP (mg/L)	0.040	0.010	0.036	0.120	0.005
Mean Organic N (mg/L)	0.70	1.57	0.35	0.95	0.56
Mean Nitrate (mg/L)	1.60	2.79	1.54	1.14	0.50
Mean Ammonia (mg/L)	0.20	0.71	0.47	0.43	0.32
5 ft DO saturation	96	86	101	148	157
Oxic water (%)	100	79	53	33	33
Secchi (ft)	7.0	4.6	3.9	3.0	3.6
Plankton (cells/L)		>100,000	2142	50220	>2 million
% bluegreen		0.0	8.2	95.0	99.3

TP = total phosphorus, SRP = dissolved (soluble reactive) phosphorus

Current Lake Management

The fishery of Ball Lake has been managed since the late-1960s (see Fisheries in Section 5). Presently, the lake is being managed as a trophy bass fishery and tiger muskies are being stocked in an effort to control an overabundance of gizzard shad.

Ball Lake has a 10 mph speed limit. There is some interest from the lake association in also legislating a horsepower limit to better control speed.

Recreational Usage

Otsego Ball Lake Association volunteers conducted several boating surveys as part of this project. One survey was conducted to identify the number and types of "resident" boats on the lake. Another survey was conducted to track boating activity on the lake, while a third survey monitored activity at the public boat launch.

For the size of the lake, there are a considerable number of "resident" boats on the lake (Table 1.2). However, during the course of the surveys, conducted both mid-week (8/1/2001) and on a Saturday (8/4/2001), the greatest number of boats active on the lake was seven and in general during the week or weekend there were typically 0 to 2 boats active on the lake (Tables 1.3 and 1.4). The greatest usage occurred Saturday evening from 4 PM to 8 PM, when there were 3 to 7 boats on the lake at any given time. This might have been due to the extremely warm temperature at the time, which discouraged day use and encouraged evening use of the lake. Most typically during the week and evening, the boats in use were paddle boats, row boats with motors, and pontoon boats, while during the weekend day the boats were primarily bass boats and fishing boats. Only four boats were observed putting in at the launch on Saturday, with a total 7 or 8 persons.

A 1996 creel study of Ball Lake was conducted by IDNR Fisheries (Ledet & Koza 1996). The study, conducted between April 14 and September 29, noted 638 hours of weekend fishing pressure, 72 percent of which was conducted by boat. During that period, 182 fish with a total weight of 69.4 pounds were caught, the majority being bluegill (67%) and crappie (30%). Also during that period, 46 bass were caught, of which 42 were released, and 26 tiger muskie were caught & released.

IDNR Fisheries also conducted a creel study in 2001, from May through September, which identified a total of 3,429 angler hours spent on the lake during that period.

Table 1.2 Resident Boats on Ball Lake	
Boat Type	Count
Pontoon boat	37
Fishing boat (primarily row boat w/motor)	25
Paddle boat	24
Sail boat	4
TOTAL	90

Table 1.3 Boat Activity on Ball Lake - August 1, 2001		
Time	Type of Boats	Count
6 AM	none	0
1 PM	canoe	1
2 PM	paddle boat	1
3 PM	none	0
4 PM	none	0
5 PM	none	0
6 PM	canoe	1
7 PM	canoe, motorboat, paddle boat, pontoon	4
8 PM	motorboat, pontoon	2

Table 1.4 Boat Activity on Ball Lake - August 4, 2001		
Time	Type of Boats	Count
6 AM	none	0
7 AM	bass boat	1
8 AM	bass boat, fishing boat	2
9 AM	bass boat	1
10 AM	bass boat	1
11 AM	none	0
12 PM	fishing boat	2
1 PM	pontoon, fishing boat	2
2 PM	pontoon (3), motorboat, paddleboat	5
3 PM	none	0
4 PM	pontoon (2), paddleboat	3
5 PM	motorboat, pontoon (2)	3
6 PM	motorboat (2), pontoon (3)	5
7 PM	pontoon (5), motorboat (2)	7
8 PM	motorboat, pontoon (4)	5

WATERFOWL POPULATION

Otsego Ball Lake Association volunteers conducted several waterfowl surveys as part of this project. One survey was conducted on July 20, 2001 and a second survey was conducted on September 22, 2001. Volunteers counted the number of waterfowl observed around the lake three times each day – morning, midday, and evening. The results from these surveys are summarized in Table 1.5. The results indicate that at any time of the day, the lake hosts from 2 to 55 waterfowl (ducks & geese) and as many as 6 Great Blue Herons. Waterfowl numbers were most consistent throughout the day in July, ranging from 43 to 55. Waterfowl numbers were lowest in the morning in September (2) and highest in early evening (53).

Table 1.5 Waterfowl in Ball Lake			
Type of Bird	morning	midday	evening
July 20, 2001	6:45 - 7:30 AM	12:15 - 12:55 PM	6:30 - 7:30 PM
Ducks	24	11	13
Geese	19	36	42
Seagulls	0	1	0
Blue Herons	4	2	1
Sept. 22, 2001	6:30 - 7:15 AM	12:30 - 1:30 PM	6:15 - 7:00 PM
Ducks	0	15	48
Geese	2	5	5
Seagulls	5	2	1
Blue Herons	3	6	3

Description of Watershed

The 7,609 acre Ball Lake watershed, located in the northeastern corner of Indiana, is bisected north and south by the county line between Stueben County to the north and DeKalb County to the south. Approximately 57 percent of the watershed is in Stueben County, while 43 percent of the watershed is in DeKalb County. The watershed is cut into approximate quarters by the towns of Steuben (29.5 percent to the NW) and Otsego (27.3 percent to the NE) in Stueben County and Smithfield (26.2 percent to the SW) and Franklin (17.0 percent to the SE) in DeKalb County.

The outlet of Ball Lake forms the headwaters of the West Branch of Fish Creek (locally Hiram Sweet Ditch). Hiram Sweet Ditch flows east from Ball Lake approximately 1.9 miles where the outlet of Hamilton Lake enters. Hiram Sweet Ditch continues on another 3.2 miles and discharges into the main branch of Fish Creek. Fish Creek flows for another 12 miles to its confluence with the St. Joseph River. The St. Joseph River flows southwest from that point for about 32 miles to Fort Wayne, where it it joins St. Mary's River and flows northeast into Ohio as the Maumee River. The Maumee River discharges into Lake Erie at Toledo.

The watershed boundary for Ball Lake was delineated with GIS using heads-up digitizing over a digital background of USGS 1:24000 topographic maps (DRGs). A large-format plot of the watershed boundary with topographic background was created and checked for errors in the office and in the field. Figure 1.1 shows the Ball Lake watershed and its location in Indiana.

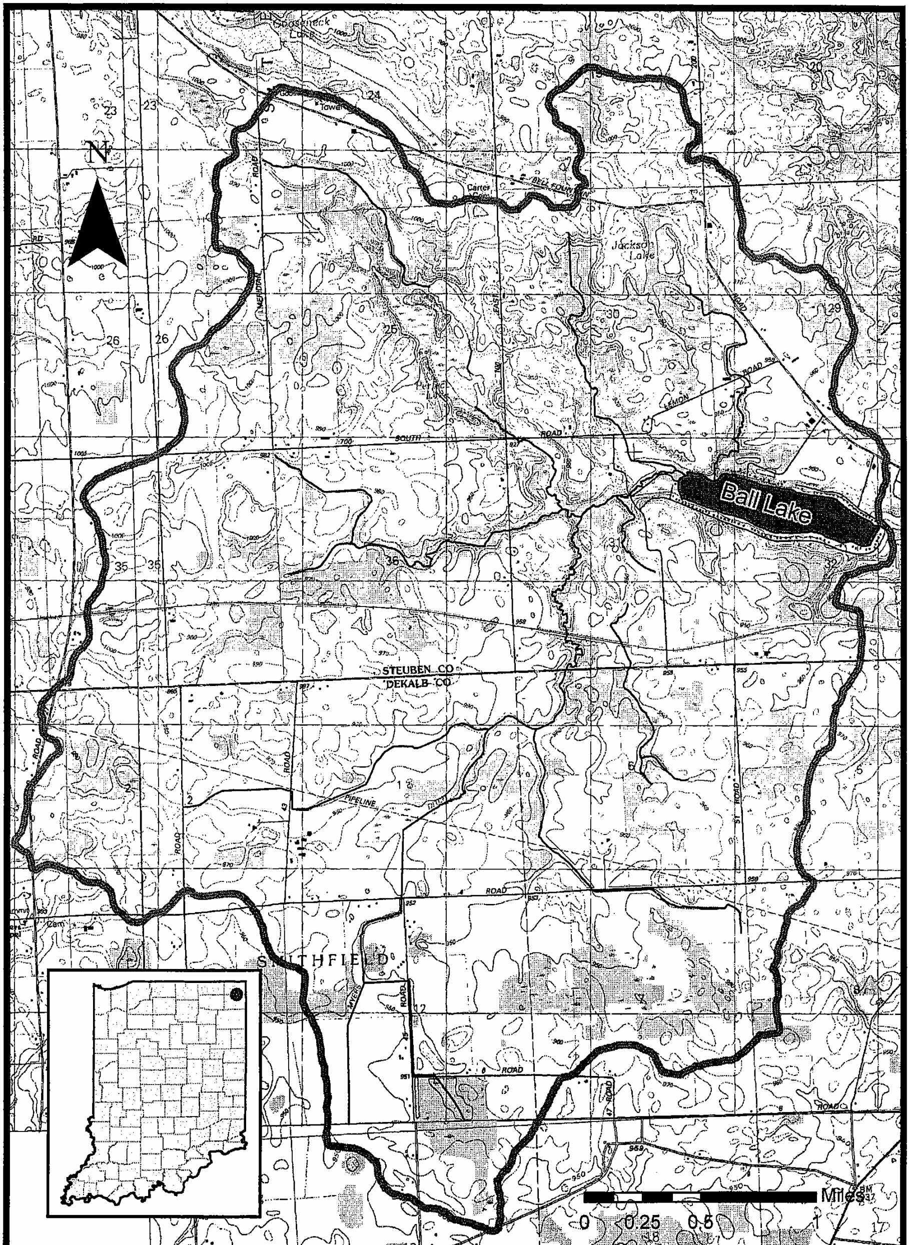

Figure 1.1 Ball Lake Watershed

Watershed Geology

The Ball Lake watershed lies within the Steuben Morainal Lake Physiographic Area, which is a complex morainal topography created by glaciers (Schneider 1966). This gives the land a rumpled, hilly and rolling nature, interspersed with wetlands and streams.

Climate

Normal Conditions

The normal climatic conditions for northeast Indiana are:

- normal precipitation: 36.17 inches, with about 28 percent falling during spring (Mar - May) and 30 percent during summer (jun - Aug) and 24 % in fall (sep - nov)
- mean annual temperature: 49.1 °F, with a mean maximum temperature of 59.2 °F and a mean minimum temperature of 39.1 °F
- warmest month is July, with a mean daily average temperature of 72.7 °F and mean daily maximum temperature of 83.9 °F
- coldest month is January, with a mean daily average temperature of 22.4 °F and mean daily minimum temperature of 14.4 °F
- 3000 growing degree days for corn

Climate during the Study

State weather records noted the following climate extremes for Fort Wayne:

- Spring 2001 was the 7th driest on record at Fort Wayne,
- July was the 4th wettest on record at Fort Wayne, and
- Summer 2001 was the 5th wettest on record at Fort Wayne.

A review of the annual climatological summary from the NCDC weather station at Angola IN was conducted. Overall, 2001 was 1.6 degrees warmer than normal and 3.64 inches wetter than normal. The highest temperature for the year of 92 °F was recorded on August 9. However, the spring and summer were drier than normal. A wet October (5.21 inches more than normal) was responsible for bringing the rainfall total for the year up. Precipitation conditions at the Waterloo weather station were generally in agreement with Angola, while Butler had variably more or less rainfall during each month. This fits with the anecdotal discussions with area residents about the patchy rainfall patterns that occurred during the summer of 2001. At times areas surrounding Ball Lake received considerable rain while the Ball Lake watershed experienced sprinkles or no rain. This weather pattern was observed directly during the week of summer field sampling in mid-August.

Topography

The topography of the Ball Lake watershed was examined using GIS and USGS digital elevation model (DEM) data. USGS 7.5 minute 30 meter DEM files were obtained for each quadrangle in the watershed. The DEM data were merged together and clipped by the watershed boundary.

The Ball Lake watershed is characterized by gentle rolling topography, with a few limited ravine areas. There is about 130 feet of elevation difference between the highest point of the watershed and the lake. The average slope in the watershed is 2.8 percent and the maximum slope is 27.3 percent. Nearly 85 percent of the watershed has slopes of 0 - 5 percent, while less then 1 percent of the watershed has slopes greater than 15 percent. Steep slopes are localized near the north shore of Ball Lake, the unnamed tributary at Hidden Canyon Preserve, and along the Cameron Ditch. A breakdown of slope in the watershed by category is presented in Table 1.6 and presented graphically in Figure 1.2.

Table 1.6
Land Slope in Ball Lake Watershed

Land Slope (%)	Percent of Watershed
0 - 5	84.38
5 - 10	11.95
10 - 15	2.82
15 - 20	0.68
20 - 25	0.15
25 - 30	0.02

SOILS

Digital soils information was provided by The Nature Conservancy and was developed as part of their St. Joseph/Fish Creek study. Due to the difference in the scale between their study and this study, the soils information does not cover the entire portion of the watershed. The TNC watershed delineation was at a much smaller scale due to its regional nature and does not precisely match up with the Ball Lake watershed at a larger scale (higher resolution). Therefore, soils information is summarized by percentage rather than total acres. Hydric soils comprise 25 percent of the soils in the watershed. Hydric soils are concentrated in the southern half of the watershed, and adjacent to both the Cameron ditch and Myers Ditch. Highly erodible soils comprise 58 percent of the soils in the watershed and are distributed evenly throughout the watershed. Together, hydric and highly erodible soils comprise 83 percent of the soils in the watershed (Figure 1.3).

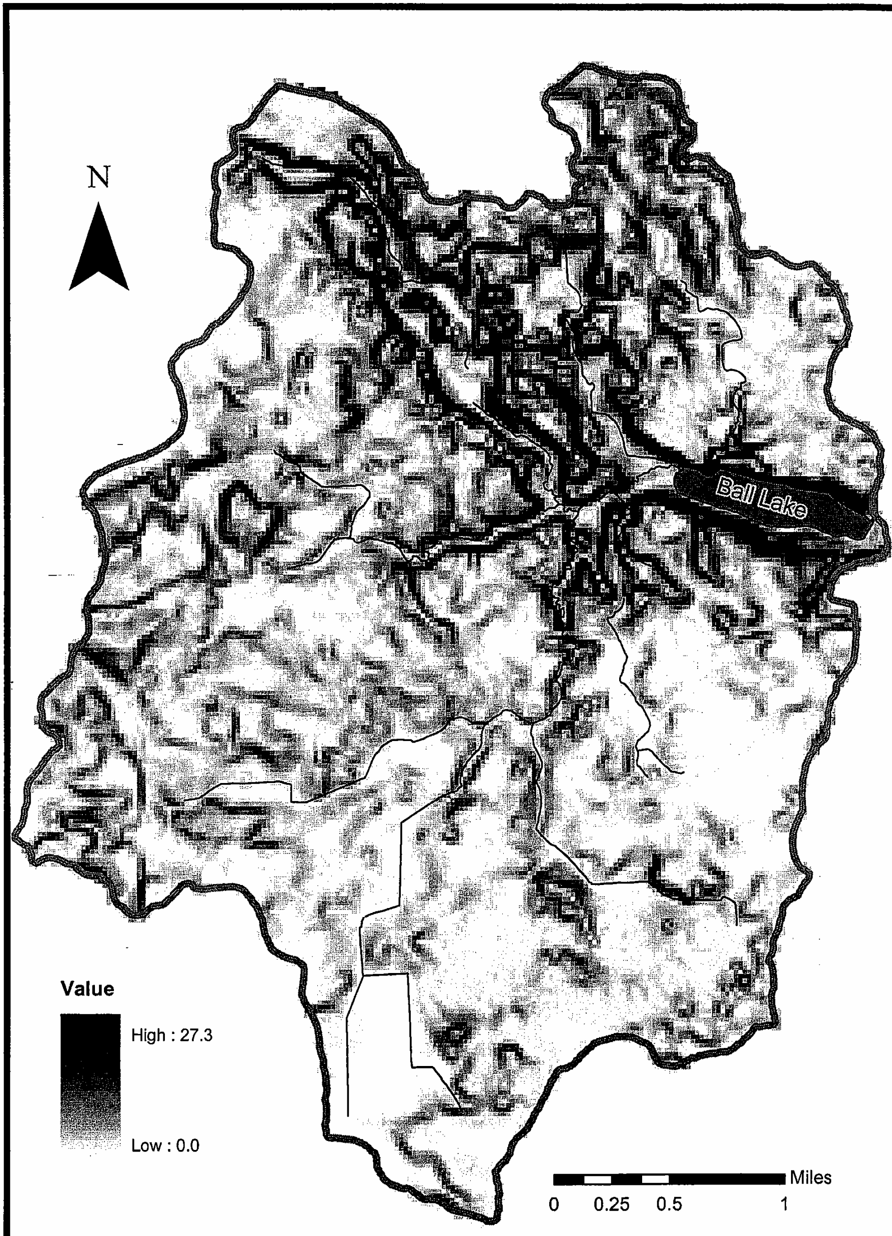

Figure 1.2 Ball Lake Watershed Slopes

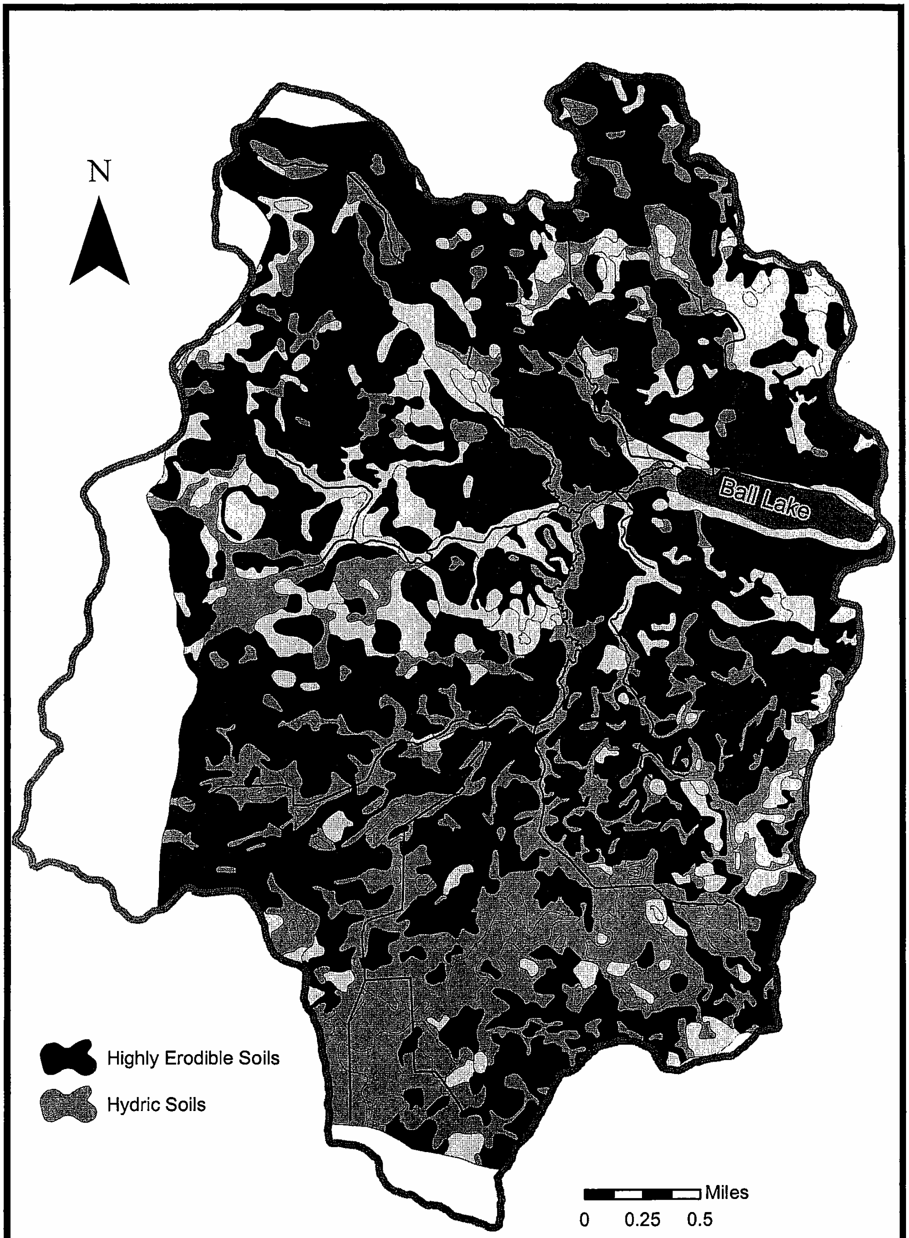

Figure 1.3 Highly Erodible and Hydric Soils in the Ball Lake Watershed (white areas = no data)

LAND USE

CURRENT LAND USE

Land use in the Ball Lake watershed was determined by GIS analysis of the National Land Cover Data (NLCD) for Indiana (USGS & US EPA 2000). The base data set for this project was leaves-off Landsat TM data, nominal-1992 acquisitions (August 1990 - Sept 1994). The spectral reflectance of the satellite imagery was converted into up to 21 land use classes based upon the NLCD Land Cover Classification System Key (Rev. July 20, 1999). The Indiana data layer was obtained in GeoTIFF file format and converted to GIS Grid format using ArcGIS. The Ball Lake watershed boundary was reprojected to match the grid projection and used to clip out a landuse grid for the watershed area. A GIS roads layer was created by heads-up digitizing of 1:24000 USGS digital topographic quadrangles (DRGs) and assigned a cover class (dirt/gravel or paved) based upon direct observation in the watershed.

Land use in the Ball Lake watershed is predominantly agricultural (nearly 80 percent), with 65.5 percent of the watershed in row crops and 14.2 percent of the watershed in pasture and hay (Figure 1.4). Deciduous forest cover accounted for 15.1 percent of the watershed area. Open water and wetlands account for 5 percent of the watershed area. Total land use in the watershed is summarized in Table 1.7. The watershed contains 11.5 miles of dirt/gravel roads, 13.5 miles of paved roads, and 3.4 miles of railroad (Figure 1.5). The watershed is sparsely populated, with the majority of homes located around Ball Lake, and the remaining watershed consisting primarily of farm properties.

LAND USE TRENDS

Undoubtedly, agriculture has been a part of this watershed for a great deal of time. Historically, this has resulted in changes to the watershed due to tiling and draining of wetlands, as well as increased sediment- and nutrient-rich runoff. However, in recent times, a large portion of the watershed is enrolled in the Conservation Reserve Program (CRP) of the USDA, resulting in well-established grass cover in many parts of the watershed. Therefore, soil erosion has been greatly reduced in comparison to historical conditions. Furthermore, cropping and fertilizer management practices have been improved, with most of the cropped acreage in soybean-corn rotation under no- or low-till practices, resulting in additional reductions in soil and nutrient runoff. During the time of the August field work, many of the ditches contained a dense vegetative cover of grasses and, although this reduces the drainage capacity of the ditches, serves to treat runoff by removing soil & nutrients.

Many of the CRP enrollments will be expiring in the near future, however, which could have a major impact on land practices within the watershed.

The shores of Ball Lake have been densely developed for many years. Presently, approximately 90 to 95 percent of the homes around Ball Lake are used as year-round residences. The homes are served by municipal water (Hamilton) or private wells. The entire lake shore has been served by Hamilton municipal sewers for about the past 20 years, with every two or three homes sharing a wastewater collection tank and grinder pump.

Although the remainder of the watershed is primarily farm properties, there have been a number of large single family homes constructed in the watershed in recent years on former agricultural lands, and several of these types of homes were under construction during this project.

Table 1.7
Land Use in the Ball Lake Watershed

Land Use	Percentage
Open Water	1.8
Low Intensity Residential	0.2
High Intensity Residential	< 0.1
Commercial/Industrial/Transportation	< 0.1
Deciduous Forest	15.1
Evergreen Forest	0.1
Mixed Forest	< 0.1
Pasture/Hay	14.2
Row Crops	65.5
Woody Wetlands	2.4
Emergent Herbaceous Wetlands	0.8

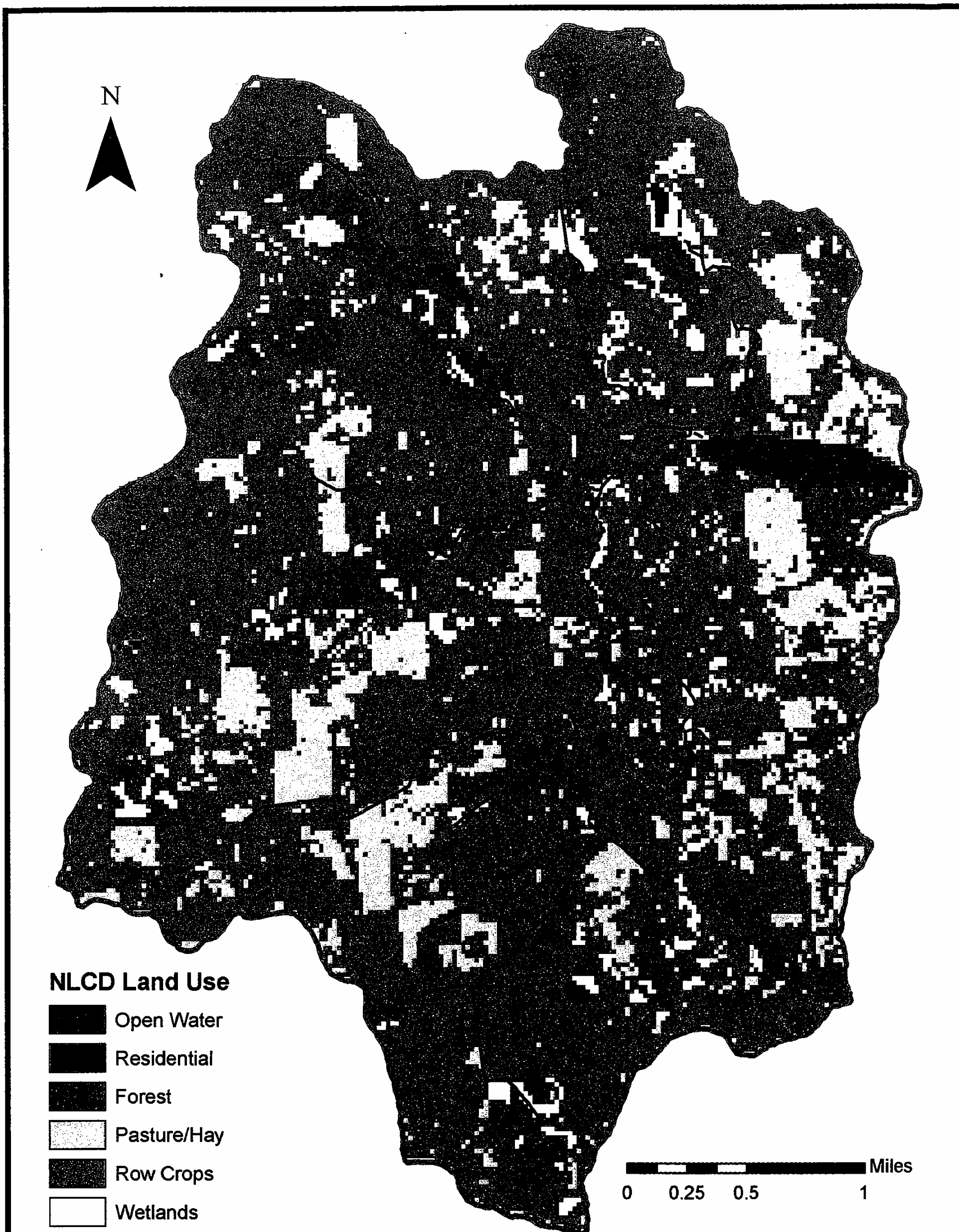

Figure 1.4 NLCD Land Use in the Ball Lake Watershed

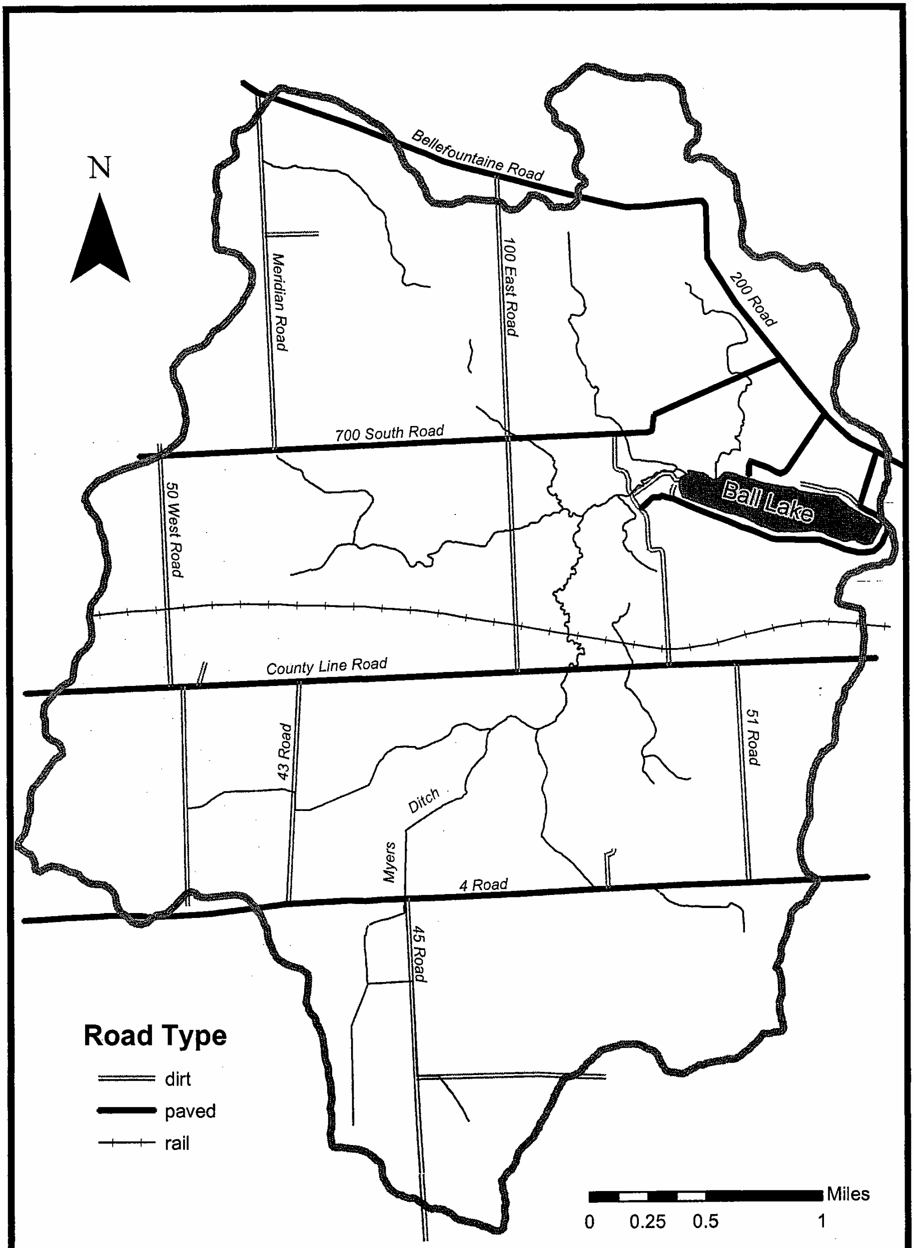

Figure 1.5 Roadways in the Ball Lake Watershed

WATER & WETLANDS

A wetlands GIS layer was created by obtaining digital National Wetlands Inventory (NWI) data for each of the topographic quadrangles in the watershed. These data were merged together and clipped by the watershed boundary to create a watershed wetlands layer. A GIS hydrology (stream) layer was created by heads-up digitizing of streams and ditches on 1:24000 USGS digital topographic quadrangles (DRGs).

Based upon GIS analysis of (NWI) data, the Ball Lake watershed contains approximately 225 wetlands with a total area of 628 acres (Figure 1.6). This represents 8.25 percent of the watershed area, which is slightly higher than the 5 percent estimate of water and wetlands based upon the NLCD satellite data. The NWI total includes two lacustrine wetlands totaling 93 acres (Ball Lake at 81.9 acres and an 11 acre unnamed waterbody just north of Perfect Lake), 12 palustrine aquatic bed (vegetated) wetlands totaling 20.2 acres, 122 emergent wetlands totaling 244.5 acres, 70 forested wetlands totaling 174.0 acres, 18 scrub-shrub wetlands totaling 54.2 acres, and 31 palustrine unconsolidated bottom (likely muck) wetlands totaling 42.2 acres. The Ball Lake watershed contains 17.0 miles of streams and ditches. It is likely that additional wetlands exist that are not identified in the NWI dataset.

Most of the stream corridors within the Ball Lake watershed are natural and unchannelized. The exceptions are the upper reaches of Myers Ditch in DeKalb County and the upper reaches of Cameron Ditch (Fish Creek) in Steuben County. The streams are generally well-shaded by forest habitat. There are no known fisheries within these streams but they may contain minnows, darters and other species typical of small streams.

FLOOD PLAIN

The stream banks in the Ball Lake watershed are generally low and vertical. The floodplains and riparian zones are generally narrow and confined by steep slopes. Exceptions to this do occur along most of the waterways, where wide forested riparian zones receive seasonal high water and where large wetland complexes exist.

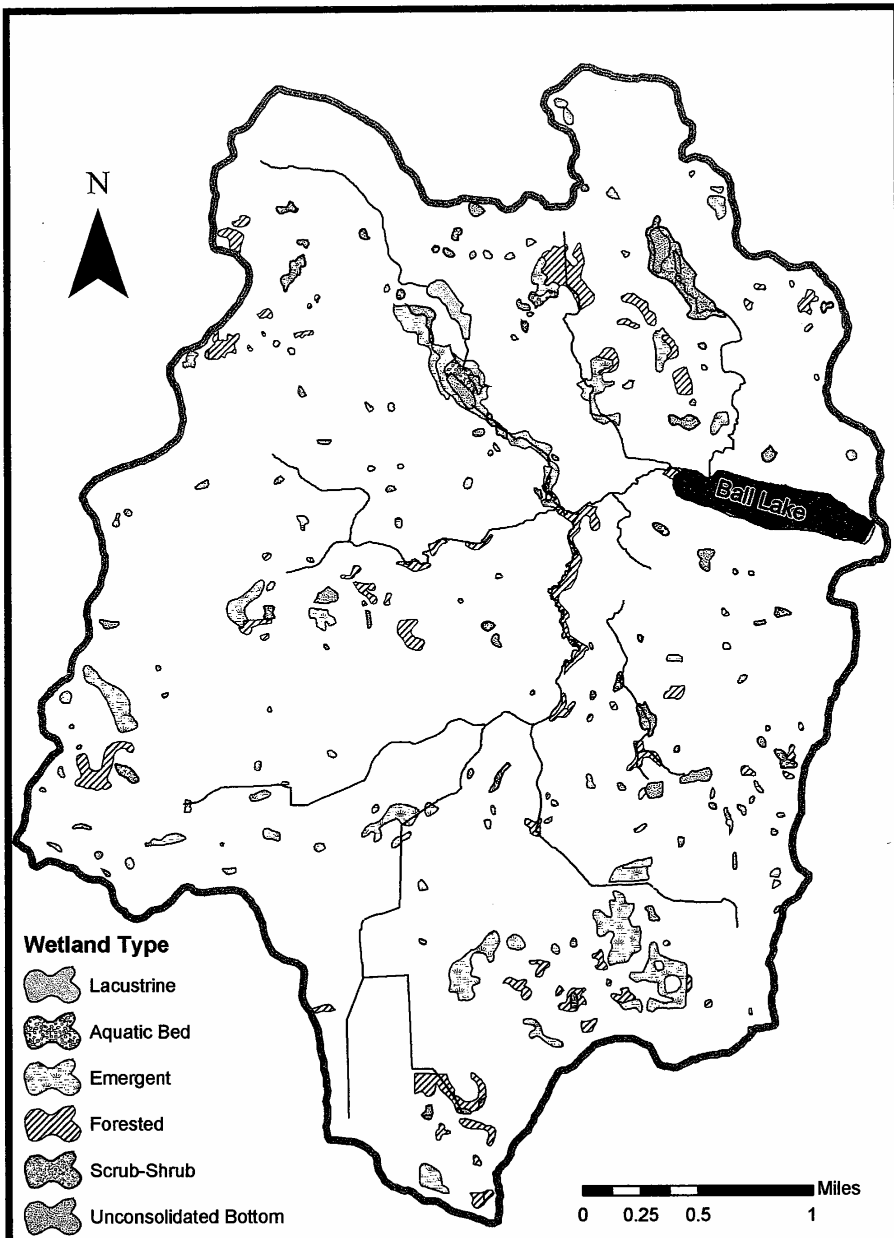

Figure 1.6 NWI Wetlands in the Ball Lake Watershed

NATURAL FEATURES[1]

The diversity of land forms in the Ball Lake watershed has created a diversity of wildlife habitats, included wetlands and grassed and forested uplands (USFWS 2001). The watershed is within the Northern Lakes Natural Region, which is part of northeastern Indiana characterized by the presence of numerous lakes of glacial origin (Homoya et al. 1985). A large variety of natural community types are found in this region, including wetlands, prarie, oak-hickory woodland, and beech-maple woodland.

The hilly morainal topography of the watershed contains numerous wetlands and small lakes. Some of the wetlands are isolated potholes created by the glacial processes which formed the region, while others are complexes of open water, aquatic bed, emergent, scrub-shrub, and forested types.

Two Nature Preserves owned by the land trust ACRES, Inc. are located near Ball Lake and within the Ball Lake Watershed (Figure 1.7). The Robb Hidden Canyon Nature Reserve is located on a small tributary to Ball Lake that enters in the southeast corner of the lake. Robb Hidden Canyon includes an excellent 35 acre beech-maple-tuliptree woodland and a 30 acre grassland. The woodland created a dense canopy and has a sparse undergrowth with an abundance of Christmas ferns. Access to the preserve is through a parking lot and trail just below the lake outlet. ACRES, Inc. is in the process of acquiring over 100 additional acres to add to the Robb Hidden Canyon Nature Reserve, which will encompass nearly the entire watershed of this small tributary to Ball Lake.

The Ball Lake Nature Preserve is a 28 acre site located along the northwest shore of Ball Lake. The preserve is located along a tributary that flows from Jackson Lake through scrub-shrub and forested wetlands and some agricultural land before entering a ravine which is contained within the preserve. The forested slopes support a beech-maple woodland and the bottomland is a seep wetland. The wetland complex between Jackson Lake and Lemon Road has the potential to support a large variety of wildlife species due to its diversity of habitats. Green heron, wood duck, mallard, and numerous songbirds can be expected to be present. There is also suitable habitat for a great blue heron rookery, but none has been reported to the Indiana Division of Fish and Wildlife. At the present time, there is no trail system to this site.

The Perfect Lake area is a privately owned high quality wetland complex of open water and aquatic bed, emergent, and scrub-shrub wetlands. The diversity of habitats in this one area likely supports a diversity of species, which <u>may</u> include State-listed species such as the spotted turtle, Blanding's turtle, Eastern massasauga, black tern, march wren, sedge wren, least bittern, king rail and various rare plants. Adjacent upland forests provide habitat for numerous songbirds, raptors, and animals.

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[1]This section excerpted from USFWS 2001

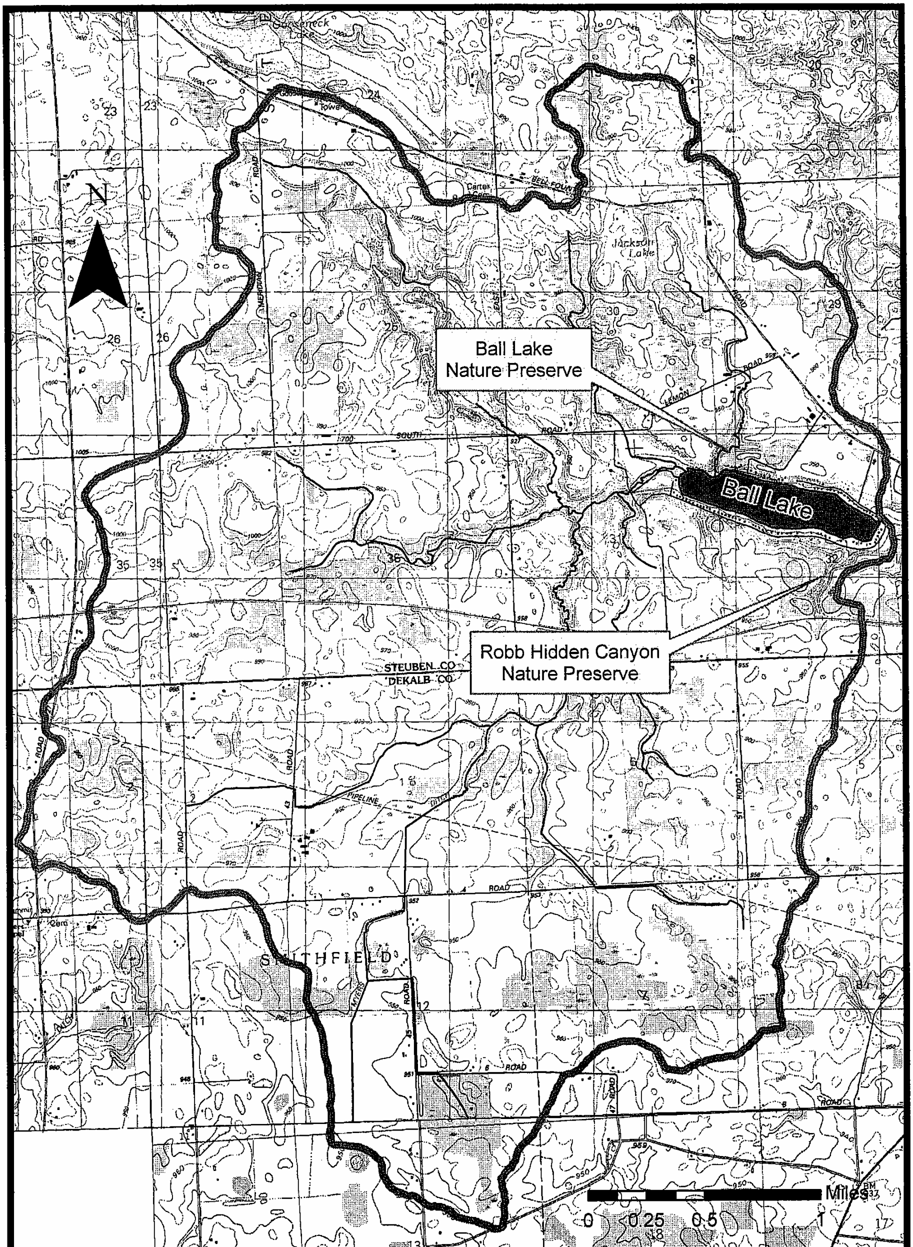

Figure 1.7 Location of Nature Preserves in the Ball Lake Watershed

The CRP grasslands and some of the pasture lands within the Ball Lake watershed provide habitat for grassland nesting birds which are experiencing major losses in habitat nationwide. US Fish & Wildlife field personnel observed bobolink and field sparrows nesting in these areas, as well as ring-necked pheasant in the watershed. Other grassland birds that may be nesting in these areas include Henslow's sparrow, upland sandpiper, dickcissels, Savannah sparrows, grasshopper sparrows, and Eastern meadowlarks.

ENDANGERED SPECIES [2]

The Ball Lake watershed is within the range of the Federally endangered Indiana bat (*Myotis sodalis*), white cat's paw pearly mussel (*Epioblasma obliquata perobliqua*), clubshell mussel (*Pleurobema clava*), and northern riffleshell (*Epioblasma torulosa rangiana*) and the threatened bald eagle (*Halieaeetus leucocephalus*) and northern copperbelly water snake (*Nerodia erythrogaster neglecta*). The various wooded stream corridors and adjacent forested uplands provide habitat for the Indiana bat. The three mussel species have been identified in the mainstem of Fish Creek below Ball Lake but are not known to occur in the Ball Lake watershed. The water snake is also present in the main stem of Fish Creek but is not currently known to be present in the Ball Lake watershed. Bald eagles are occasional winter visitors to lakes in northern Indiana and may be observed at Ball Lake and other area lakes, but there is no specific habitat for them in the watershed and they do not nest in the area.

UNIQUE RECREATIONAL RESOURCES

Despite problems with an unbalanced fishery, Ball Lake is still considered one of the better fishing opportunities in northeastern Indiana for trophy largemouth bass and is also a destination for tiger muskie fishing. In 1983, IDNR Fisheries noted that, on per acre basis, Ball Lake supported one of the largest largemouth bass populations of any northern Indiana lake (Ledet 1983). Beyond that, the watershed offers some excellent opportunities to observe its unique landforms and its habitat and wildlife diversity.

PROBLEM AREAS

Major water quality problem areas within the watershed are generally associated with the streams and streambanks. Much of the soils in the watershed are highly erosive, and while land use/agricultural practices have helped minimize erosion on the uplands, the streams themselves cut deeply into these soils. Consequently, significant amounts of erosion occurs along the stream banks during periods of high flow.

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[2]This section excerpted from USFWS 2001

LAKE WATER QUALITY

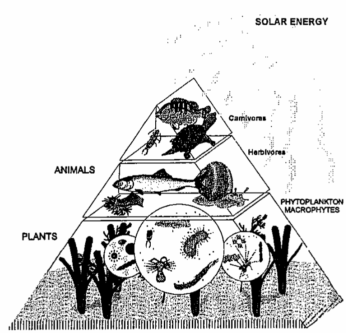
METHODOLOGY

Water quality monitoring was conducted following standard accepted practices for lake survey work modified to meet the needs of the LARE program and IDEM Eutrophication Index. Samples were collected on August 15, 2001 during the early afternoon (around 1 PM) from a boat anchored over the deep portion of the lake (Figure 2.1). Instruments (YSI dissolved oxygen and LiCor light meters) were calibrated in the field according to manufacturer's directions. Water samples were collected using a vertical kemmerer bottle, placed into appropriate sample bottles containing any necessary preservatives, and immediately placed in a cooler with ice. Field measurements with the dissolved oxygen and light meters were both recorded into meter memory and written onto field data sheets. Chlorophyll *a* and phytoplankton samples were collected by collecting a 2 meter composite using the kemmerer bottle. A vertical plankton tow was not collected from 1 percent light level (3.7 m) as prescribed for the IDEM Eutrophication Index since the lake contained a bloom of *Cylindrospermopsis* and no plankton were visually apparent in the phytoplankton tows conducted in the field.

Chlorophyll *a* samples were filtered on shore. All samples were then shipped priority overnight to the F. X. Browne, Inc. laboratory in Marshalls Creek, PA. Sample analyses were conducted following Standard Methods (APHA 1992).

LAKE ECOLOGY PRIMER

THE ENERGY PYRAMID



The ecological condition of any lake is the summation of the physical, chemical, and biological processes that occur within it. Temperature and dissolved oxygen measurements are usually reliable means of evaluating the ecological condition of a lake. Life processes in the upper, well-lit waters result in the uptake of nutrients by algae and in the resultant production of oxygen and organic material. At the lake bottom, the absence of light results in an environment which is colder than the surface and often reduced or devoid of dissolved oxygen. Photosynthetic production by green plants is the predominant life process at the surface while bacterial decomposition of organic matter is the predominant process at the bottom. The supply of dissolved oxygen at the bottom may be depleted by bacterial decomposition and by various chemical processes associated with nutrient cycling.

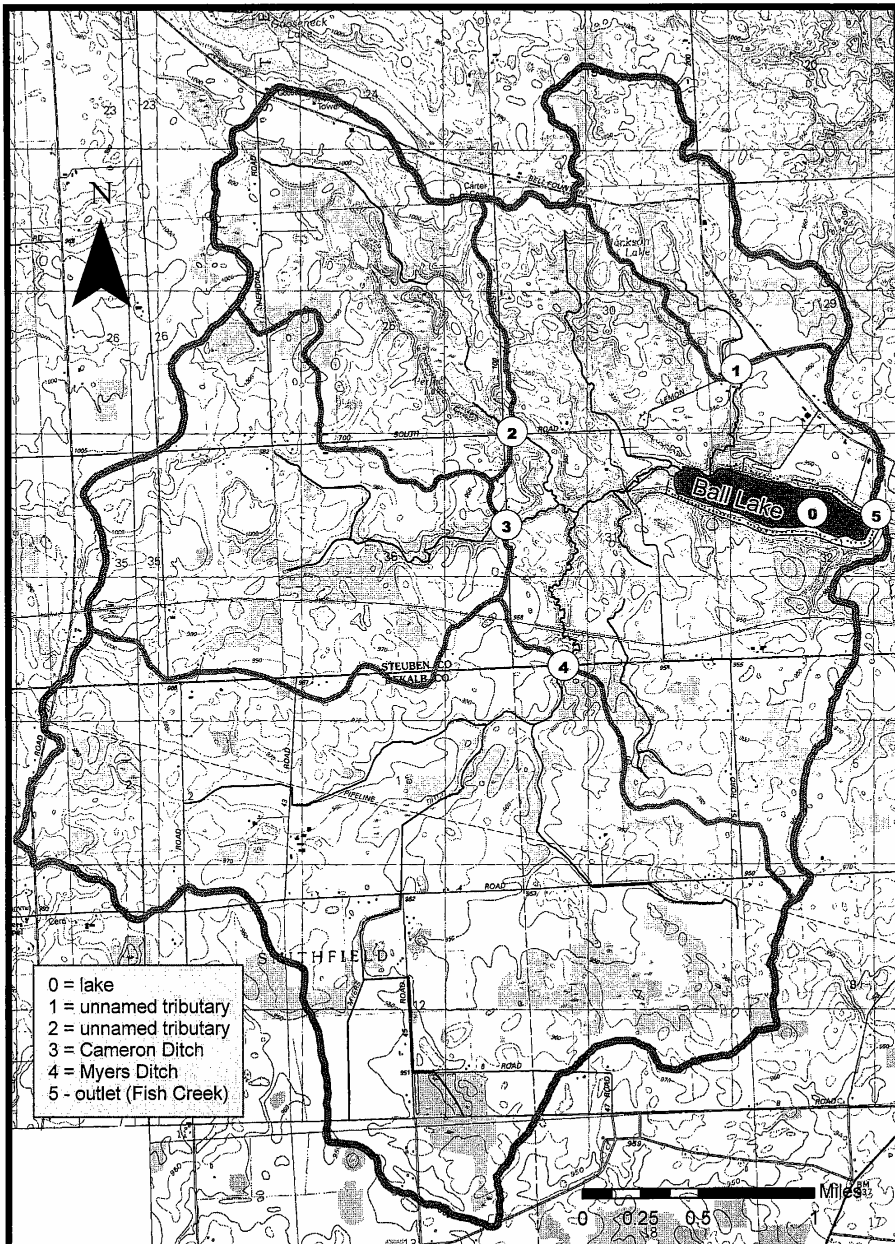


Figure 2.1 Location of Sampling Stations and Subwatersheds in Ball Lake Watershed

Dissolved oxygen is necessary to support most forms of aquatic life. A minimum dissolved oxygen concentration of 5.0 milligrams per liter is required to support most fish. Warm water fish, such as bass and perch, often survive at lower oxygen levels. Oxygen levels in a lake are directly related to the physical, chemical and biological activities occurring in the lake water. Dissolved oxygen measurement is therefore an excellent indicator of the overall water quality of a lake. Additional information about a lake is gained by monitoring for nutrient levels, transparency, and the amount and types of algae present.

Although a lake may appear to be in equilibrium, two types of natural long-term successional changes occur: (1) the lake gradually fills in with sediment from the erosion of streams and surrounding land areas; and (2) eroded sediments deposited into the lake are usually rich in nutrients which stimulate increased plant growth. The process is further accelerated by the increase of organic nutrients derived from dead plants and animals as the number of organisms increase within the lake. This process, called succession or aging, causes the lake to fill in and become shallower. As it continues, the types of animals and plants within the lake's ecosystem also begin to change. Game fish such as bass, pike, and pan fish may be replaced by rough species such as carp, suckers, and bullheads. Rough fish are better adapted to live in a lake which is relatively old on the time scale of succession. As the process of filling in continues, eventually the lake or pond becomes a herbaceous and shrub/scrub wetland. If conditions are right, a forested wetland takes over. Depending on environmental conditions, the process of natural succession may take hundreds or even thousands of years. The actions of man, however, can considerably accelerate this aging process.

Lake water quality is a direct reflection of the water quality of the watershed. The term "watershed" is defined as all lands that eventually drain or flow into a lake (..."all waters that are shed to a lake"). Potential sources of water to lakes are streams (tributaries), surface runoff (overland flow from lakeside properties), groundwater (interflow), and precipitation. The water quality of these water sources are greatly influenced by watershed characteristics including soils, geology, vegetation, topography, climate, and land use. Typical land uses encountered in a watershed are wetlands, forests, agriculture, residential, commercial, and industrial. With regards to water quantity, larger watersheds contribute larger volumes of water to lakes and vice versa.

The water quality of Ball Lake is the result of chemical, physical, and biological interactions of the aquatic system within the lake. Nutrients such as nitrogen and phosphorus, as well as suspended solids, are present in the stormwater runoff from the forested and agricultural land throughout the entire watershed. Eventually, the sediment and nutrient-laden stormwater enters the tributaries and is ultimately deposited in Ball Lake. Nutrients and sediments are also present in overland flow, which is deposited directly from the lands adjacent to the lake.

RESULTS

UNITS OF MEASURE

Results are often presented as concentrations in milligrams per liter (mg/L) or its equivalent of parts per million (ppm) and micrograms per liter (µg/L) or its equivalent of parts per billion (ppb). The various units of measure are related as follows:

1 mg/L = 1 ppm; 1 µg/L = 1 ppb, 1 ppm = 1,000 ppb
0.020 mg/L (ppm) = 20 µg/L (ppb)

SUMMARY OF RESULTS

Results of the water quality survey of Ball Lake are summarized in Table 2.1. The individual parameters are discussed in the sections that follow.

Table 2.1
Summary of Ball Lake Water Quality Data

Parameter	Epilimnion (1.5 m)	Hypolimnion (16 m)
pH (s.u.)	8.7	7.4
Turbidity (NTU)	5.57	6.63
Conductivity (µmhos)	308	416
Total Phosphorus (mg/l)	0.016	0.126
Soluble Phosphorus (mg/l)	0.001	0.009
Total Kjheldahl Nitrogen (mg/l)	0.43	1.32
Nitrate/Nitrite (mg/l)	0.45	0.54
Ammonia (mg/l)	0.15	0.49
Chlorophyll *a* (µg/L)	15.3	n/a
Transparency (m)	1.1	n/a

DISSOLVED OXYGEN AND TEMPERATURE

The amount and distribution of dissolved oxygen in a lake ecosystem can affect the health of aquatic organisms and nutrient cycles. For normal growth and reproduction, adult warm water fish (i.e. bass and pike) require oxygen concentrations of at least 5.0 milligrams per liter (mg/L), and adult cold water fish (i.e. trout and salmon) require at least 6.5 mg/L of dissolved oxygen (US EPA 1986). Lakes receive most of their oxygen from the atmosphere through gas exchange at the surface. In deeper lakes that stratify, the cold bottom water (hypolimnion) is isolated from the oxygen entering the upper water (epilimnion). If the lake sediments are rich in organic matter, bacterial decomposition uses up the oxygen in the bottom waters and the hypolimnion becomes anoxic (without oxygen). If this occurs, cold water fish habitat is lost, and phosphorus within the sediments may be released into the overlying water.

The dissolved oxygen and temperature profile data for Ball Lake are presented in Table 2.2 and Figure 2.2. The upper waters of the lake were supersaturated with oxygen due to the presence of an intense bloom of the blue-green bacteria, *Cylindrospermopsis*. Ball Lake was essentially anoxic (without oxygen) below a depth of 4 meters (13.1 feet) and throughout the entire hypolimnion (cool bottom waters).

Table 2.2
Dissolved Oxygen and Temperature Data for Ball Lake

Depth (m)	DO (mg/L)	Temp (ºC)	DO (%)	Depth (ft)
0.0	12.16	27.2	153.15%	0.0
1.0	12.72	26.9	159.34%	3.3
2.0	12.53	26.0	154.43%	6.6
3.0	10.81	25.5	132.02%	9.8
3.5	4.63	23.5	54.49%	11.5
4.0	1.76	22.5	20.32%	13.1
5.0	0.37	17.5	3.87%	16.4
6.0	0.33	13.5	3.17%	19.7
7.0	0.32	11.7	2.95%	23.0
8.0	0.31	10.4	2.77%	26.2
9.0	0.34	8.8	2.93%	29.5
10.0	0.31	7.8	2.60%	32.8
11.0	0.31	7.3	2.57%	36.1
12.0	0.31	6.8	2.54%	39.4
13.0	0.31	6.4	2.52%	42.7
14.0	0.30	6.1	2.42%	45.9
15.0	0.30	5.8	2.40%	49.2
16.0	0.29	5.7	2.31%	52.5
17.0	0.29	5.5	2.30%	55.8
18.0	0.29	5.4	2.29%	59.1
19.0	0.28	5.4	2.22%	62.3

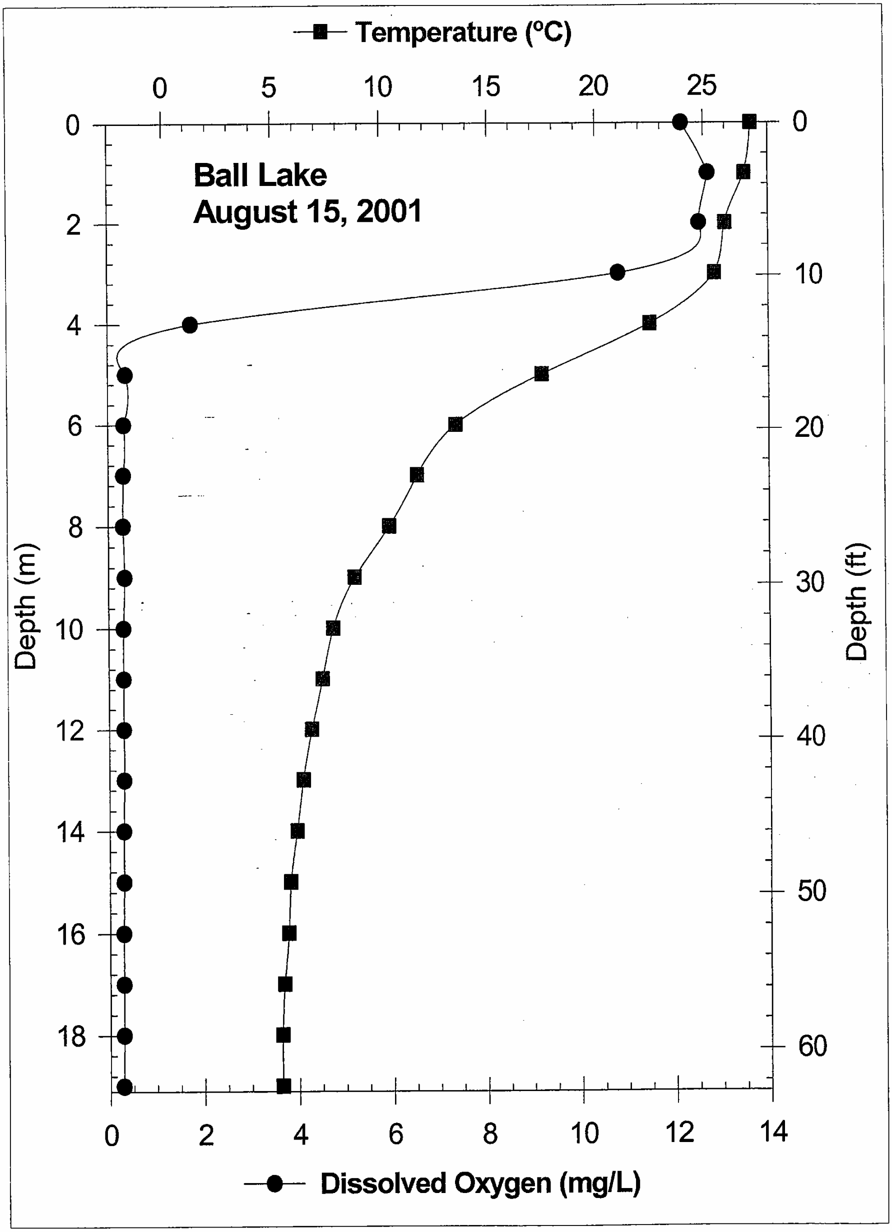


Figure 2.2 Dissolved oxygen and temperature profile for Ball Lake

pH

The pH level is a measure of acidity (concentration of hydrogen ions in water), reported in standard units on a logarithmic scale that ranges from one to fourteen. On the pH scale, seven is neutral, lower numbers are more acid, and higher numbers are more basic. In general, pH values between 6.0 and 8.0 are considered optimal for the maintenance of a healthy lake ecosystem. Many species of fish and amphibians have difficulty with growth and reproduction when pH levels fall below 5.5 standard units. Lake acidification status can be assessed from pH as follows:

pH less than 5.0	Critical (impaired)
pH between 5.0 and 6.0	Endangered (threatened)
pH greater than 6.0	Satisfactory (acceptable)

The pH of Ball Lake was 8.7 in the epilimnion and 7.4 in the hypolimnion. Ball Lake has historically had pH values in the range of 8 to 9 standard units.

Conductivity

Conductivity is a measure of the ability of water to conduct electric current, which is related to the amount of dissolved ions within the water. Higher conductivity values are indicative of pollution by road salt or septic systems <u>or</u> more eutrophic conditions in a lake. Conductivities may be naturally high in water that drains from bogs and marshes. Clean, clear-water lakes might typically have conductivities of less than 100 micromhos per centimeter (µmhos/cm), and eutrophic lakes have conductivities greater than 100 µmhos/cm.

The conductivity of Ball Lake was 308 in the epilimnion and 416 in the hypolimnion, indicating eutrophic conditions exist in the lake.

Nitrogen

Nitrogen is one of the three main nutrients of life, along with phosphorus and carbon. Most forms of nitrogen occur naturally in low concentrations in surface waters, while high concentrations may indicate pollution from wastewater, including septic system leachate, and agricultural activities. Nitrate is an inorganic form of nitrogen. Organic nitrogen is un-oxidized, organically bound form of nitrogen that includes proteins, peptides, urea, and numerous synthetic compounds. High organic nitrogen increases the oxygen demand in aquatic systems. Ammonia is a form of nitrogen that can be toxic to aquatic organisms at elevated concentrations. Total nitrogen is a measure of all forms of nitrogen, including organic nitrogen, ammonia, and inorganic forms.

In general, nitrogen values were relatively low in Ball Lake for all of the measured forms. This would suggest that agricultural practices within the watershed are providing good stewardship of the land relative to the runoff of nutrients.

Phosphorous

Phosphorus is one of the three main nutrients of life, along with nitrogen and carbon. In the United States, phosphorus is the nutrient that most often controls productivity of lake systems. Total phosphorus is a measure of all forms of phosphorus, both organic and inorganic. Total phosphorus concentrations are directly related to the trophic condition (water quality status) of a lake. Excessive amounts of phosphorus lead to algae blooms and loss of oxygen in lakes. In general, epilimnetic (surface water) total phosphorus concentrations less than 10 micrograms per liter (µg/L) are associated with oligotrophic (clean, clear water) conditions and concentrations greater than 25 µg/L are associated with eutrophic (nutrient-rich) conditions (US EPA 1990).

Phosphorus concentrations were low in the upper waters and elevated in the bottom waters of Ball Lake. The average total phosphorus concentration of 0.071 mg/L was lower than historical values due in part to a low epilimnetic concentration of 0.016 mg/L. These low values are likely a result of improved agricultural land stewardship in recent years and due to a reduction in phosphorus runoff as a result of lower than normal precipitation earlier in the year. The elevated concentration of phosphorus in the hypolimnion of 0.126 mg/L indicates that phosphorus is being recycled out of the sediments and into the water column under anoxic conditions.

Limiting Nutrient

Phytoplankton growth depends on a variety of nutrients, including macronutrients such as phosphorus, nitrogen, and carbon, along with trace nutrients, such as iron, manganese, and other minerals. According to Liebig's law of the minimum, biological growth is limited by the substance that is present in the minimum quantity with respect to the needs of the organism. Nitrogen and phosphorus are usually the nutrients limiting algal growth in most natural waters. By controlling the amount of the limiting nutrient present in a lake, you can control the amount of phytoplankton growth.

Depending on the species, algae require approximately 15 to 26 atoms of nitrogen for every atom of phosphorus. This ratio converts to 7 to 12 mg of nitrogen per 1 mg of phosphorus on a mass basis. A ratio of total nitrogen to total phosphorus of 15:1 is generally regarded as the dividing point between nitrogen and phosphorus limitation (U.S. EPA, 1980). Identification of the limiting nutrient becomes more certain as the total nitrogen to total phosphorus ratio moves farther away from the dividing point, with ratios of 10:1 or less providing a strong indication of nitrogen limitation and ratios of 20:1 or more strongly indicating phosphorus limitation.

Inorganic nutrient concentrations may provide a better indication of the limiting nutrient because the inorganic nutrients are the forms directly available for algal growth. Ratios of total inorganic nitrogen (TIN = ammonia, nitrate, and nitrite) to dissolved reactive phosphorus (DRP) greater than 12 are indicative of phosphorus limitation, ratios of TIN:DRP less than 8 are indicative of nitrogen limitation, and TIN:DRP ratios between 8 and 12 indicate either nutrient can be limiting (Weiss, 1976).

The total phosphorus to total nitrogen (TN:TP) ratios and the total inorganic nitrogen to dissolved reactive phosphorus (TIN:DRP) ratios were determined for Ball Lake. The ratios were determined based on the results of the samples collected in mid-August 2001 and are shown in Table 2.3. Based on the TN:TP and the TIN:DRP ratios, Ball Lake was extremely phosphorus-limited at the time of sampling, indicating both that there was a ready supply of nitrogen available and that the amount of phosphorus present was regulating phytoplankton growth.

Table 2.3
Nitrogen to Phosphorus Ratios in Ball Lake

TN:TP Ratio	TIN:DRP Ratio
64.6	600

Notes: (1) TN:TP, Total Nitrogen Concentration / Total Phosphorus Concentration
(2) TIN:DRP, Total Inorganic Nitrogen Concentration / Dissolved Reactive Phosphorus Concentration

TURBIDITY

Turbidity is a measure of the cloudiness of a lake. The clarity of a lake is a major determinant in the condition and productivity of that system. Turbidity in water is caused by suspended matter, such as silt and clay, finely divided organic and inorganic matter, soluble organic color compounds, and plankton and other microscopic organisms. Turbidity measures the optical scattering and absorption of light by the presence of these factors in water. Higher turbidity values are indicative of the presence of one or more of the turbidity-causing factors is present in a sample, but can not indicate which factor or factors is at fault.

Turbidity in Ball Lake was relatively low, at 5.6 NTU in the epilimnion and 6.6 NTU in the hypolimnion. Measured turbidity was likely caused primarily by the presence of the algae bloom that was underway at the time of sampling.

CHLOROPHYLL A

Chlorophyll *a* is the green pigment in plants used for photosynthesis, and measuring it provides information on the amount of algae (microscopic plants) in lakes. Chlorophyll *a* concentrations can also be used to classify lake trophic state. In general, chlorophyll *a* concentrations less than 4 micrograms per liter (µg/L) are associated with oligotrophic conditions, while concentrations greater than 10 µg/L are associated with eutrophic conditions (US EPA 1990).

Chlorophyll *a* in Ball Lake was 15.3 µg/L, which corresponds to a moderately eutrophic water body.

Transparency & Light Profile

Transparency is a measure of water clarity in lakes and ponds. It is determined by lowering a 20 cm black and white disk (Secchi disk) into a lake to the depth where it is no longer visible from the surface. Since algae are the main determinant of water clarity in non-stained lakes that lack excessive amounts of inorganic turbidity (suspended silt), transparency is used as an indicator of lake trophic state. In general, transparencies greater than 4.0 meters (13.1 feet) are associated with oligotrophic conditions, while transparencies less than 2 meters (6.6 feet) are associated with eutrophic conditions (US EPA 1990).

Ball Lake had a transparency of 1.1 meters (3.6 feet), corresponding to a lake with moderately eutrophic water quality. The measured light profile from Ball Lake is presented in Table 2.4.

Table 2.4
Light Profile for Ball Lake

Depth in m (ft)	Light Transmission (percent)
0 (0.0)	100.00
1 (3.3)	89.90
2 (6.6)	30.23
3 (9.8)	8.11
4 (13.1)	0.66
5 (16.4)	0.22
6 (19.7)	0.09
7 (23.0)	0.03

Phytoplankton

Phytoplankton results from the Ball Lake water quality survey are presented in Table 2.5. The phytoplankton of Ball Lake was dominated almost entirely by the presence of a bloom of *Cylindrospermopsis*, a toxic bluegreen bacteria. No zooplankton were observed in vertical or horizontal net samples taken on the sampling date, likely due to the effect of *Cylindrospermopsis* toxins. *Cylindrospermopsis* bloom densities ranged from 210,000 cells per mL (Wagner, 2002) to 320,000 cells per mL (St. Amand, pers. comm. 2001).

Table 2.5 Phytoplankton Density & Biomass in Ball Lake		
Taxon	Density #/mL	Biomass µg/L
BACILLARIOPHYTA	60	43.5
Navicula	15	7.5
Nitzschia	30	24.0
Synedra	15	12.0
CHLOROPHYTA	900	426.0
Chlamydomonas	840	336.0
Scenedesmus	60	90.0
CRYPTOPHYTA	690	1104.0
Cryptomonas	690	1104.0
CYANOPHYTA	236,250	2362.5
Oscillatoria	26,250	262.5
Cylindrospermopsis	210,000	2100.0
PYRRHOPHYTA	30	63.0
Peridinium	30	63.0
TOTAL	237,930	3999.0

ABOUT CYLINDROSPERMOPSIS[3]

Cylindrospermopsis raciborski has a unique place among the other toxic blue-green algae because it is an exotic that likely invaded the United States in the late 1970's to early 1980's. *Cylindrospermopsis* is microscopic and can be extremely toxic in high concentrations. *Cylindrospermopsis* is considered a subtropical alga (originally identified from India in 1913) and does well in high nutrient, high temperature, stable waters. Ball Lake satisfied these criteria in August 2001. In the last 10-15 years Cylindrospermopsis has been spreading throughout North America, particularly west and north from its original observations in Florida.

Cylindrospermopsis raciborski is a toxic, filamentous blue-green alga. Unlike other common toxic blue-green algae, *Cylindrospermopsis* is small and indistinct at first glance. The filaments are often only 2-3 um wide and the curled morph (form)which was dominant in Ball Lake is only 10-20 um long. *Cylindrospermopsis* has several characteristics that also distinguishes it from among the other toxic blue-green algae. It often stays well distributed

[3]This section courtesy Dr. Ann St. Amand, PhycoTech, Inc.

throughout the water column and has the highest concentrations below the surface. In fact, other than a deep green-brown color, its often difficult to determine that a serious blue-green bloom is occurring at all.

Cylindrospermopsis produces at least three distinct toxins. Cylindrospermopsin, anatoxin-a and saxitoxin all can be highly toxic and in high enough doses, lethal to animals (cattle, alligators and dogs seem to be the hardest hit) and potentially humans. Lower levels of exposure, such as swimming in water where *Cylindrospermopsis* is moderately blooming, can cause skin rashes and stomach problems. Long term exposure to low levels of toxins, like microcystin, have been linked to cancer as well. Another characteristic unique to *Cylindroperspermopsis* is that it seemingly always produces toxin. Sampling for toxins was conducted in Ball Lake after the bloom dissipated. Cylindrospermopsin was detected at very low levels in those samples but there is know way to determine what the maximum toxin levels might have been during the *Cylindrospermopsis* bloom.

The World Health Organization (WHO) has developed action limits for cell densities of all toxic blue-green species, based on assuming an equivalent response to similar levels of microcystin. From 5000-20,000 cells/ml, there is a relatively mild risk of adverse health affects, from 20,000-100,000 cells/ml, there is a moderate risk of adverse health affects and over 100,000 cells/ml, there is a high risk of potentially severe, long-term health affects. As with most other waterborne diseases, those people in high risk categories are at increased risk for adverse health affects such as children, the elderly and anyone with a history of cancer or AIDS. Cell densities in Ball Lake were well over the 100,000 cell/ml limit for posing a high risk of potentially severe, long-term health affects during the August, 2001 bloom. A health advisory was issued by the State on August 21, 2001. The advisory was lifted on August 30, 2001 after the toxin analysis was completed.

WATER QUALITY INDICES

Water quality indices are used to describe a lake's trophic state or water quality status. Oligotrophic lakes have few algae and macrophytes and appear clean and clear, while eutrophic lakes show an overabundance of growth and often have a pronounced green color due to algae. Eutrophication is a natural process whereby lakes increase in trophic state over long periods of time. However, the process of eutrophication can be greatly accelerated by human activities (such as watershed development and sewage disposal) which introduce additional nutrients, organic matter and sediment into the lake system. This cultural eutrophication can be reversed by controlling human inputs, but in many cases additional in-lake treatments are required in order to accelerate this rehabilitation process.

IDEM EUTROPHICATION INDEX

The Indiana Department of Environmental Management (IDEM) has established a set of criteria for determining the trophic state of Indiana water bodies called the IDEM Eutrophication Index. The index is a trophic continuum ranging from 0 to 75 and is calculated as the sum of eutrophy points determined for a number of water quality parameters. Once the index has been calculated, a lake's trophic state can be classified as follows:

IDEM Eutrophication Index of 0 to 25 points - Highest Quality, Oligotrophic
IDEM Eutrophication Index of 36 to 50 points - Intermediate Quality, Mesotrophic
IDEM Eutrophication Index of 51 to 75 points - Lowest Quality, Eutrophic

The IDEM Eutrophication Index criteria and results for Ball Lake are presented in Table 2.6. Nutrient concentrations for the purposes of assigning eutrophy points were calculated as the average of epilimnetic (surface) and hypolimnetic (bottom) sample results. The phytoplankton score on the IDEM Index for Ball Lake may be deceptively high, since the *Cylindrospermopsis* bloom consisted of a large number of organisms but very little biomass. In addition, this count is based on a two meter whole water composite count rather than a vertical plankton tow collected from the 1% light level (3.7 m) since no phytoplankton were observed in the field in net tow samples. Based upon the whole water plankton analysis, the Plankton Component of the Index (X) yields 35 points whether or not one includes the Cylindrospermopsis. Presumably the other phytoplankton would have been trapped in a vertical tow, and the counts were so high that even if a four meter composite was collected and the lower two meters of water were devoid of phytoplankton, the score would not have changed.

Table 2.6
IDEM Eutrophication Index

Parameter and Range	Eutrophy Points	Ball Lake Score
I. Total Phosphorus (ppm)		
A. At least 0.03	1	
B. 0.04 to 0.05	2	3
C. 0.06 to 0.19	3	(0.07 ppm)
D. 0.2 to 0.99	4	
E. 1.0 or more	5	
II. Soluble Phosphorus (ppm)		
A. At least 0.03	1	
B. 0.04 to 0.05	2	0
C. 0.06 to 0.19	3	(0.005 ppm)
D. 0.2 to 0.99	4	
E. 1.0 or more	5	
III. Organic Nitrogen (ppm)		
A. At least 0.5	1	
B. 0.6 to 0.8	2	1
C. 0.9 to 1.9	3	(0.56 ppm)
D. 2.0 or more	4	
IV. Nitrate (ppm)		
A. At least 0.3	1	
B. 0.4 to 0.8	2	2
C. 0.9 to 1.9	3	(0.5 ppm)
D. 2.0 or more	4	

Table 2.6 IDEM Eutrophication Index		
Parameter and Range	Eutrophy Points	Ball Lake Score
V. Ammonia (ppm)		1 (0.3 ppm)
A. At least 0.3	1	
B. 0.4 to 0.5	2	
C. 0.6 to 0.	3	
D. 1.0 or more	4	
VI. Dissolved Oxygen (%saturation at 5 ft from surface)		4 (157%)
A. 114% or less	0	
B. 115% to 119%	1	
C. 120% to 129%	2	
D. 130% to 139%	3	
E. 150% or more	4	
VII. Dissolved Oxygen (% of water column with at least 0.1 ppm)		3 (33%)†
A. 76% or more	0	
B. 66% to 75%	1	
C. 50% to 65%	2	
D. 29% to 49%	3	
E. 28% or less	4	
VIII. Light Penetration (Secchi disk)		6 (3.6ft)
A. Over five ft	0	
B. Five ft or less	6	
IX. Light Transmission (percent light transmission at 3 ft)		0 (90.8%)
A. 71% or more	0	
B. 51% to 70%	2	
C. 31% to 50%	3	
D. 30% or less	4	
X. Total Plankton (organisms per liter)		35 (237,930,000/L)‡ (99 % bg) (w/out *Cylindro*) 27,930,000/L (94 % bg)
A. less than 3,000	0	
B. 3,000 to 6,000	1	
C. 6,001 to 16,000	2	
D. 16,001 to 26,000	3	
E. 26,001 to 36,000	4	
F. 26,001 to 60,000	5	
G. 60,001 to 95,000	10	
H. 95,001 to 150,000	15	
I. 150,001 to 500,000	20	
J. greater than 500,000	25	
K. blue-green dominance	add 10 points	
	BALL LAKE TOTAL	55

† Only 33 % of water column was oxygenated. The remaining water column had about 0.30 mg/L of dissolved oxygen, which for the purposes of the IDEM should be considered anoxic. The difference between 0.1 mg/L and 0.3 mg/L is slight and could be attributed to meter calibration error.
‡Based upon a 2 m whole water composite

The IDEM eutrophic index for Ball Lake has increased 1975, based upon IDEM Clean Lakes data, from 34 to 55. Values in 1989 and 1992 were lower than in 1975, at 24 and 21, respectively. However, since 1992, the Indiana TSI has increased steadily, with a TSI of 46 in 1997 and a 2001 value of 55.

CARLSON TSI

The Carlson (1977) Trophic State Index (TSI) is a useful valuable tool for the evaluation the water quality status of lakes. The index can be calculated using total phosphorus, chlorophyll *a*, and/or transparency (Secchi depth) data. The trophic state of a lake is best characterized using summer averages for each of these parameters. To calculate this index each seasonal average is logarithmically converted to a scale of relative trophic state ranging from 1 to 100. This index was constructed such that an increase in ten units represents a doubling in algal biomass. For example, a lake with a chlorophyll TSI of 40 has twice as much algae as a lake with a TSI value of 30. Also, the index was designed so that under phosphorus limiting conditions, and where algae are the main factor affecting transparency, TSI values calculated from Secchi depth, total phosphorus and chlorophyll *a* data should be very similar.

The Carlson TSI values for Ball Lake are presented in Table 2.7. Ball Lake was moderately eutrophic based upon the TSI values for transparency and chlorophyll *a*, and mesotrophic based upon total phosphorus. The lower total phosphorus value relative to the chlorophyll *a* and transparency values is likely due to the presence of a bloom of *Cylindrospermopsisis*, which was able to reproduce in large numbers despite relatively low phosphorus concentrations being present in the epilimnion.

Table 2.7
Carlsons TSI Values for Ball Lake

Parameter	TSI Value
Total Phosphorus	44.2 (mesotrophic)
Chlorophyll *a*	57.3 (eutrophic)
Secchi Transparency	58.6 (eutrophic)

It was not possible to examine the trend in Carlson's TSI for Ball Lake, since historical chlorophyll *a* data and historical epilimnetic total phosphorus data were not generally available.

DISCUSSION

The significant issues identified by the water quality monitoring program were the anoxic hypolimnion, and the identification of a bloom of toxic bluegreen bacteria. The sediments of the lake are releasing phosphorus into the hypolimnion under anoxic conditions, resulting in a buildup of phosphorus in the bottom waters of the lake. With phosphorus being the limiting nutrient in Ball Lake, this phosphorus may be supplying the necessary resources to support phytoplankton blooms through vertical entrainment across the thermocline (migration of phosphorus into the warmer surface waters). As a result, even though phosphorus concentrations are low in the epilimnion of the lake, phytoplankton are able to grow and reproduce in great abundance, causing an aesthetic nuisance at the very least and, in the case of *Cylindrospermopsis* or other toxic bluegreen bacteria, causing a potential public health threat.

STREAM WATER QUALITY

STREAM WATER QUALITY SAMPLING METHODOLOGY

WATER QUALITY

Wet and dry weather stream sampling was accomplished by the collection of grab samples that were placed in appropriately preserved sample containers, place on ice, and shipped or delivered to the laboratories for analysis. Stream flows were determined by measuring a cross-sectional profile and measuring interval flow across a stream transect. Sample bottle contamination during field collection prevented the reliable analysis of wet weather samples at Station 4 for specific conductance and wet weather samples at Station 5 for pH, conductivity, and turbidity. Ammonia analysis was not part of the contract for this project and was therefore not analyzed on wet weather samples. However, ammonia analysis was added to the dry weather sampling event to comply with IDNR recommendations described in "Draft Scope of Services for Preliminary Diagnostic Study.[4]"

Sampling locations are presented in Figure 2.1. Subwatershed areas at each station are presented in Table 3.1.

Table 3.1
Drainage (Subwatershed) Areas for Sampling Stations

Station	Area (ac)
Station 1	46.7
Station 2	84.8
Station 3	112.4
Station 4	278.2

MACROINVERTEBRATES & HABITAT ASSESSMENT

Macroinvertebrate collection and analysis were conducted on the two main inlets to Ball Lake following EPA's Rapid Bioassessment Protocols (Barbour et al. 1999). Field collection was conducted at Station 3 (Cameron Ditch) and Station 4 (Myers Ditch)on August 15, 2001. Appropriate riffle areas were selected at each station and macroinvertebrates were collected using a Surber stream bottom sampler. Macroinvertebrates were separated from larger materials collected during the sampling process. The remaining material and macroinvertebrates were placed in a collection jar and preserved in the field using 70 percent

[4]IDNR website, http://www.state.in.us/dnr/soilcons/lare/scopeprellakediag.htm

ethanol. Macroinvertebrate samples were analyzed according to the U.S. EPA Rapid Bioassessment II Protocol. Ideally, a count would be made to a minimum of 100 organisms. However, neither station contained that many organisms so all individuals from each station were identified to the family level. The metrics calculated were Total Taxa-Chironomids, Hilsenhof Biotic Index (HBI), Modified EPT richness, Modified Percent EPT, Percent Dominant Taxon, and Percent Intolerant Taxa. Total taxa-chironomids represents the number of different taxa present when all the chironomids are counted as one family, Chironomidae, rather than different genera. HBI is a commonly used index of specific benthic macroinvertebrate tolerances to organic pollution. Modified EPT richness and Modified Percent EPT are indices of the three taxa that are most intolerant to pollution, Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichopera (caddisflies). The modified version doesn't include the taxa with HBI values higher than 5. Percent dominant taxon is a measure of the relationship between the number of individuals in the most dominant taxon to the population as a whole. Percent Intolerant Taxa is the percentage of macroinvertebrate families present that are intolerant of pollution.

Habitat assessment was conducted using the Qualitative Habitat Evaluation Index (QHEI) method (Rankin 1989, Rankin 1995, OhioEPA 1999) at Stations 3 and 4 following the collection of macroinvertebrate samples. At each site, field personnel discussed each metric and its options and reached a consensus before making an entry, taking into account stream conditions at, above, and below the sampling point. Calculations of metric 6, Map Gradient, were made with the assistance of GIS.

RESULTS

WATER QUALITY

Results of the wet and dry weather monitoring of the Ball Lake tributary stations are presented in Tables 3.2 and 3.3, respectively. Phosphorus concentrations were generally moderate to high in both wet and dry weather conditions, while nitrogen concentrations were generally low to moderate. Stream flow was extremely low during the dry weather sampling period, and the weather preceding sample collection had been dry. Therefore, some of the elevated results are likely the result of concentration effects (lack of dilution plus evaporation). For instance, conductivity was generally higher under dry weather conditions than wet weather. In general, however, there was little difference in the water chemistry between wet and dry weather periods. Fecal coliform bacteria were more numerous in wet weather.

Based upon these data, Station 3 and Station 4 had the worst water quality under wet weather conditions and Station 4 had the worst water quality during low flow conditions. These two stations tended to have the highest turbidity and highest concentrations of nutrients and bacteria. Under both wet and dry conditions, Station 4 had the highest concentrations of total and soluble phosphorus. Therefore, priority ranking for watershed treatment for sediment and phosphorus controls would be as follows, in order from highest to lowest subwatershed priority: Station 4 (Myers Ditch subwatershed), Station 3 (Cameron Ditch subwatershed), Station 1 (Perfect Lake subwatershed), Station 2 (Jackson Lake subwatershed).

Table 3.2 Summary of Ball Lake Tributary Water Quality Data • Wet Weather • June 7, 2001					
Parameter	Station 1	Station 2	Station 3	Station 4	Station 5
pH (s.u.)	7.8	8.0	7.9	7.3	¤
Turbidity (NTU)	4.0	5.6	24.9	22.3	¤
Conductivity (µmhos)	91.8	447.0	404.0	¤	¤
Total Phosphorus (mg/l)	0.053	0.057	0.158	0.240	0.030
Soluble Phosphorus (mg/l)	0.066	0.004	0.066	0.146	0.038
Total Kjheldahl Nitrogen (mg/l)	0.36	0.45	0.66	0.77	0.31
Nitrate/Nitrite (mg/l)	0.22	0.20	0.58	0.16	0.19
Ammonia (mg/l)	†	†	†	†	†
Fecal coliform (#.100 mL)	141	89	416	570	56
Dissolved oxygen (mg/L)	9.4	9.8	9.8	9.4	8.6
Temperature (°C)	17.0	20.0	16.0	16.0	20.0

†not analyzed
¤sample contamination

Table 3.3 Summary of Ball Lake Tributary Water Quality Data • Dry Weather • August 15, 2001					
Parameter	Station 1	Station 2	Station 3	Station 4	Station 5
pH (s.u.)	8.1	7.9	7.8	8.2	8.7
Turbidity (NTU)	5.2	2.8	10.9	11.0	5.2
Conductivity (µmhos)	554.0	425.0	577.0	770.0	313.0
Total Phosphorus (mg/l)	0.060	0.056	0.066	0.203	0.021
Soluble Phosphorus (mg/l)	0.005	0.002	0.005	0.028	0.001
Total Kjheldahl Nitrogen (mg/l)	0.56	0.96	0.46	0.63	1.20
Nitrate/Nitrite (mg/l)	0.20	0.01	0.65	0.95	0.43
Ammonia (mg/l)	0.12	0.11	0.10	0.10	0.10
Fecal coliform (#.100 mL)	80	171	46	30	4
Dissolved oxygen (mg/L)	8.9	6.8	3.7	7.8	10.6
Temperature (°C)	13.8	18.3	16.3	16.3	25.3

Macroinvertebrate Survey

The types of macroinvertebrates present in a stream are indicative of the quality of the water. A healthy stream will have good species diversity, with many different taxa represented in the sample. In an impacted stream, most of the individuals will be represented by only a few taxa. An HBI of 0 indicates good water quality while an HBI of 10 represents poor water quality. A high EPT Index and Percent EPT represent good water quality, since the three orders of macroinvertebrates represented by those metrics are intolerant to pollution and are usually not found in impacted streams. In streams with good water quality, the percent dominant species will be low, which is an indication of good species diversity.

Results of the macroinvertebrate surveys are presented in Tables 3.4 and 3.5. Based upon these indices, both stations could be considered to slightly to moderately impacted. The lack of at least 100 organisms may indicate a greater degree of impact, but this might be more related to the low flow conditions present as a result of the lack of rainfall the region had been experiencing prior to the study. Myers Ditch, with a lower total number of organisms but a higher percentage of intolerant taxa, appeared to be slightly less impacted than Cameron Ditch.

Table 3.4 Macroinvertebrate Counts for Ball Lake Tributaries				
TAXA	Common name	HBI	Station #3	Station #4
EPHEMEROPTERA				
Heptageriidae	mayfly	3	4	7
PLECOPTERA				
	stonefly			
TRICHOPTERA				
Polycentrapodidae	caddisfly	6	2	
Hydropsychidae	caddisfly	5		4
Leptoceridae	caddisfly	4	1	
MEGALOPTERA				
Sialidae	alderfly	4	1	
COLEOPTERA				
Elmidae	Riffle Beetle	5	13	4
COLEMBOLA				
Isotomuridae	springtail	5	1	
GASTROPODA				
Ancylidae	snail	7		2
Physidae	snail	8		2
PELECYPODA				
Sphaeriidae	clam	8		2
DIPTERA				
Chironomidae	midge	6	3	10
Tipulidae	crane fly	4	14	2
Tabanidae	horse/deer fly	6	8	
OLIGOCHAETA	worm	10	1	
		TOTALS	48	33

Table 3.5 Macroinvertebrate Results for Ball Lake Tributaries		
Metric	Station 3 Cameron Ditch	Station 4 Myers Ditch
Total Taxa-Chironomids	10	8
Hilsenhof Biotic Index (HBI)	5.0	5.3
Modified EPT richness*	2	2
Modified Percent EPT*	20%	25%
Percent Dominant Taxon	29%	30%
Percent Intolerant Taxa	29%	48%

* The metrics that are listed as modified (*) do not include taxa with HBI values > 5

HABITAT SURVEY

The Qualitative Habitat Evaluation Index (QHEI) is a physical habitat index designed by Ohio EPA to provide a quantified evaluation of the general stream habitat characteristic that are important to fish communities. Various attributes of the habitat are scored based on the overall importance of each to the maintenance of viable, diverse, and functional aquatic faunas. The QHEI consists of six separate metrics which are calculated separately and then summed together for a maximum score of 100. The type(s) and quality of substrates, amount and quality of instream cover, channel morphology, extent and quality of riparian vegetation, pool, run, and riffle development and quality, and gradient are some of the metrics used to determine the QHEI score. The QHEI score gives an estimate of the suitability of a stream segment to provide warmwater habitat for aquatic organisms, and can be interpreted as follows:

- QHEI > 75: Steam segment capable of supporting exceptional warmwater faunas
- QHEI > 60: Unimpaired - Stream segment suitable for Warmwater Habitat without use impairment
- QHEI between 45 and 60: Slightly impaired - Stream segment may meet Warmwater Habitat in some circumstances, but it may show a level of impairment that requires classification as Modified Warmwater Habitat
- QHEI between 32 and 45: Moderately impaired - Stream segment meets Modified Warmwater Habitat
- QHEI < 32: Severely impaired - Stream segment may be suitable for Modified Warmwater Habitat only if the watershed is greater than 3 square miles. Even then, this may not be possible. Where Modified Warmwater Habitat is not possible, the stream segment is classified as a Limited Resource Water.

The completed QHEI Field/Calculation Sheets for Stations 3 and 4 are provided in Appendix B and summarized in Table 3.6. The results of the QHEI evaluation indicate that Cameron Ditch at Station 3, with a QHEI of 42, exhibited a moderate level of impairment. Myers Ditch at Station 4, with a QHEI of 54, exhibited a slight level of impairment.

Table 3.6 Summary of QHEI Results		
QHEI Metric	Station 3	Station 4
1) Substrate (Max = 20)	8	15
2) Instream Cover (Max = 20)	6	8
3) Channel Morphology (Max = 20)	8	8
4) Riparian Zone & Bank Erosion (Max = 10)	10	10
5a) Pool/Glide Quality (Max = 12)	1	4
5b) Riffle/Run Quality (Max = 8)	3	3
6) Gradient (Max = 10)	6	6
TOTALS	42	54

DISCUSSION

The main tributaries of Ball Lake are generally slight to moderately impacted, based upon the results of both the chemical and biological surveys. Good to excellent land stewardship throughout the watershed, together with the abundance of natural wetlands and ponds, has mitigated many of the expected effects one typically finds in an agriculturally-dominated watershed.

Several issues of concern were identified by the stream monitoring, however. First, a strong hydrocarbon odor was noticeable in the stream samples during dry weather sampling when they were added to acid-filled containers for preservation. Hydrocarbon odor in streams may indicate pesticide and/or herbicide contamination. Stream monitoring also identified an increase in fecal coliform contamination under wet weather conditions. While some fecal coliform may be naturally occurring, there are also areas in the watershed with little or no vegetated buffers between agricultural lands and streams and ditches, which may increase the likelihood of pathogenic contamination.

SEDIMENTS, BATHYMETRY, AND SHORELINE CONDITION

METHODOLOGY

Lake bathymetry and sediment thickness maps were created using a recording (paper chart) fathometer. The transponder was mounted onto a stable boat and numerous transects were made across the lake at a steady speed. Depth and sediment thickness points were then transferred to digital outline map of the lake based upon the relative distance along the strip chart and the corresponding computerized transect. Contours of bathymetry and sediment thickness were then hand-digitized to create the final maps.

Information from the bathymetric mapping was fed into a computer program in order to calculate basic morphometric parameters (Martin 1994). Volume calculations were made using the truncated cone method, which sums up the volumes between each lake contour and assumes the lake sides approximate a cone. Surface area at each depth contour was derived from the digitized contours using GIS.

Shoreline condition was assessed by boat cruising at slow speeds around the lakeshore in mid-August 2001. Areas of natural shoreline were noted, as were various bulkheads. Areas of erosion and types of shoreline bulkheads and modifications were marked on a field map. This information was later transferred to a digital map.

RESULTS

LAKE BATHYMETRY & MORPHOLOGY

Ball Lake has a court-established regulated water level of 894.76 feet above MSL and a high water level of 899.91 feet above MSL. A bathymetric map of Ball Lake is presented in Figure 4.1. Based upon this study, Ball Lake has the following morphometric configuration:

surface area: 343,028 m^2 (84.76 ac)
maximum depth: 19.5 m (64 ft)
mean depth: 12.2 m (40 ft)
relative depth: 3.0 (maximum depth as percentage of surface area)
lake volume: 4,181,820 m^3 (147.7 million ft^3)
hypolimnetic volume: 1,333,700 m^3 (47.1 million ft^3)
(approx. 32 percent of the entire lake volume)
shore length: 3,259 meters (10,692 ft)
shoreline configuration: 1.57 (relative roundness: round lake = 1)

The north and south shores, which run the length of Ball Lake, tend to be steep, with depths quickly dropping off near shore. The bottom of the lake is relatively flat beyond the steeply sloped sides. The west (inlet) and east (outlet) ends of the lake are shallower and gently sloping out a considerable distance from shore before dropping off to the depths of the lake.

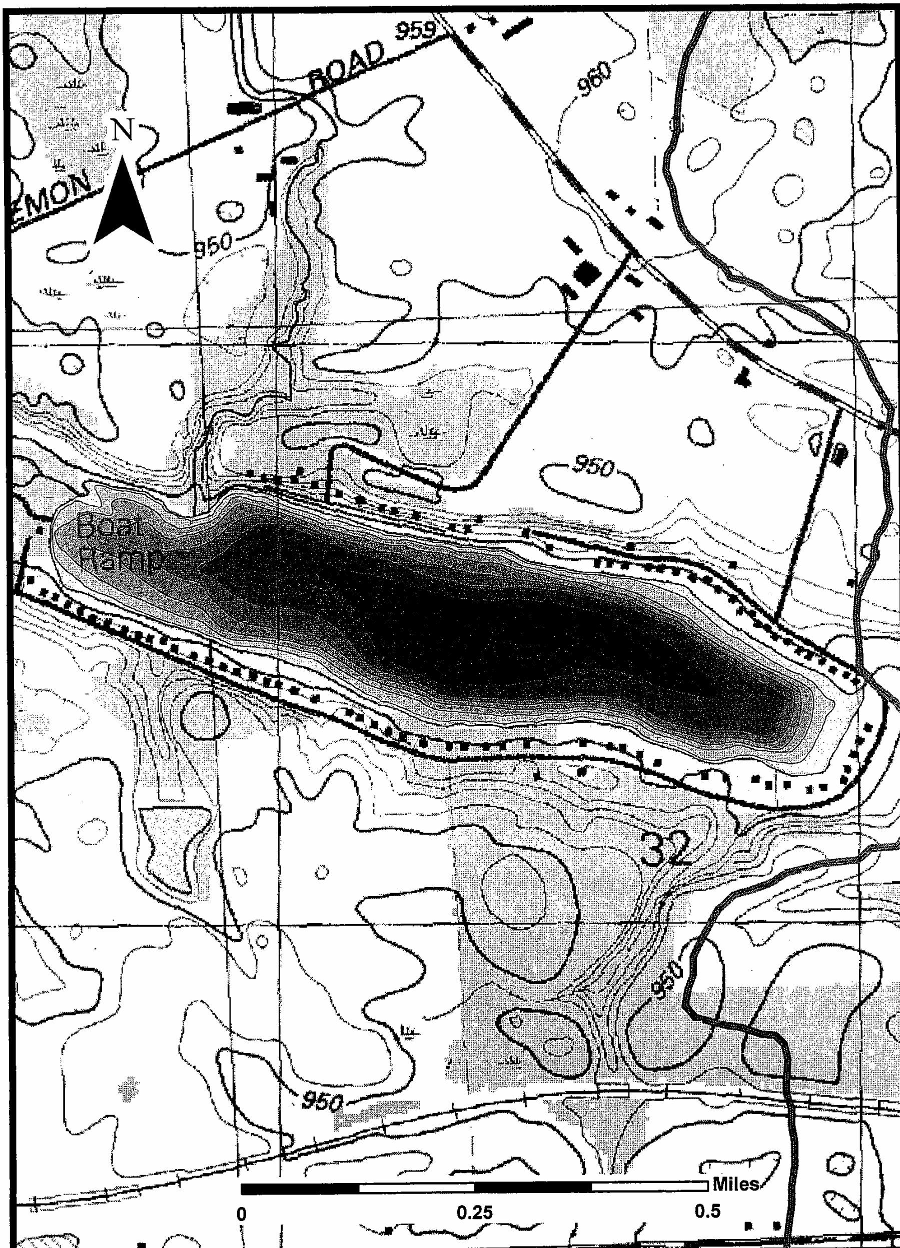


Figure 4.1 Bathymetric Map of Ball Lake (10 foot contours)

Lake Sediments

Sediment thickness in Ball Lake generally ranged from 5 to 11 feet, with the deepest sediments having accumulated in the middle of the lake its deepest point. A sand and gravel bar is present at the main inlet of the lake, coming to within a few inches of the lake surface. A much smaller sand and gravel bar is present at the mouth of a smaller inlet on the northwest shore of the lake. This small sand bar is located at the mouth of the tributary that drains the Station 1 subwatershed. Turbidity at the sampling station was low. Sediments that accumulate in the lake here may originate from the steep ravine located in the Ball Lake Reserve, which lies below the sampling station.

Shoreline Condition Survey

The results of the shoreline survey are presented in Table 4.1 and Figure 4.2. No areas of significant erosion were observed along the shores of Ball Lake. Approximately 5,272 feet (50 percent) of the shoreline had some sort of armoring installed. Most of this armoring distracts very little from the natural look of the shore, being primarily placed stone/round rock at the waterline or low horizontal wood walls or logs. A photograph of typical shoreline condition is presented in Figure 4.3.

Table 4.1
Shoreline Armor at Ball Lake

Bulkhead/Armor Type	Total Length (ft)
stone (primarily placed round rock)	3,274
log (horizontal wood)	907
concrete	710
wood (vertical plank or piling)	318
metal (sheet pile)	63
TOTAL LENGTH	5,272

Discussion

Ball Lake is a narrow, steep sided basin with a deep, flat center. Sedimentation has accumulated as sand and gravel bars at the mouths of two inlets. Neither of these were considered to be an issue for lake management due to the overall steepness of the shore and depth of the lake. Little or no shoreline erosion is evident around the lake and most of the shoreline protection features in place blend well with the natural look of the lake. There is, however, a definite lack of a vegetated buffer along the shoreline in front of most of the properties. Naturalized plantings would help to filter direct runoff to the lake, providing a water quality benefit while enhancing the aesthetic character of the lake.

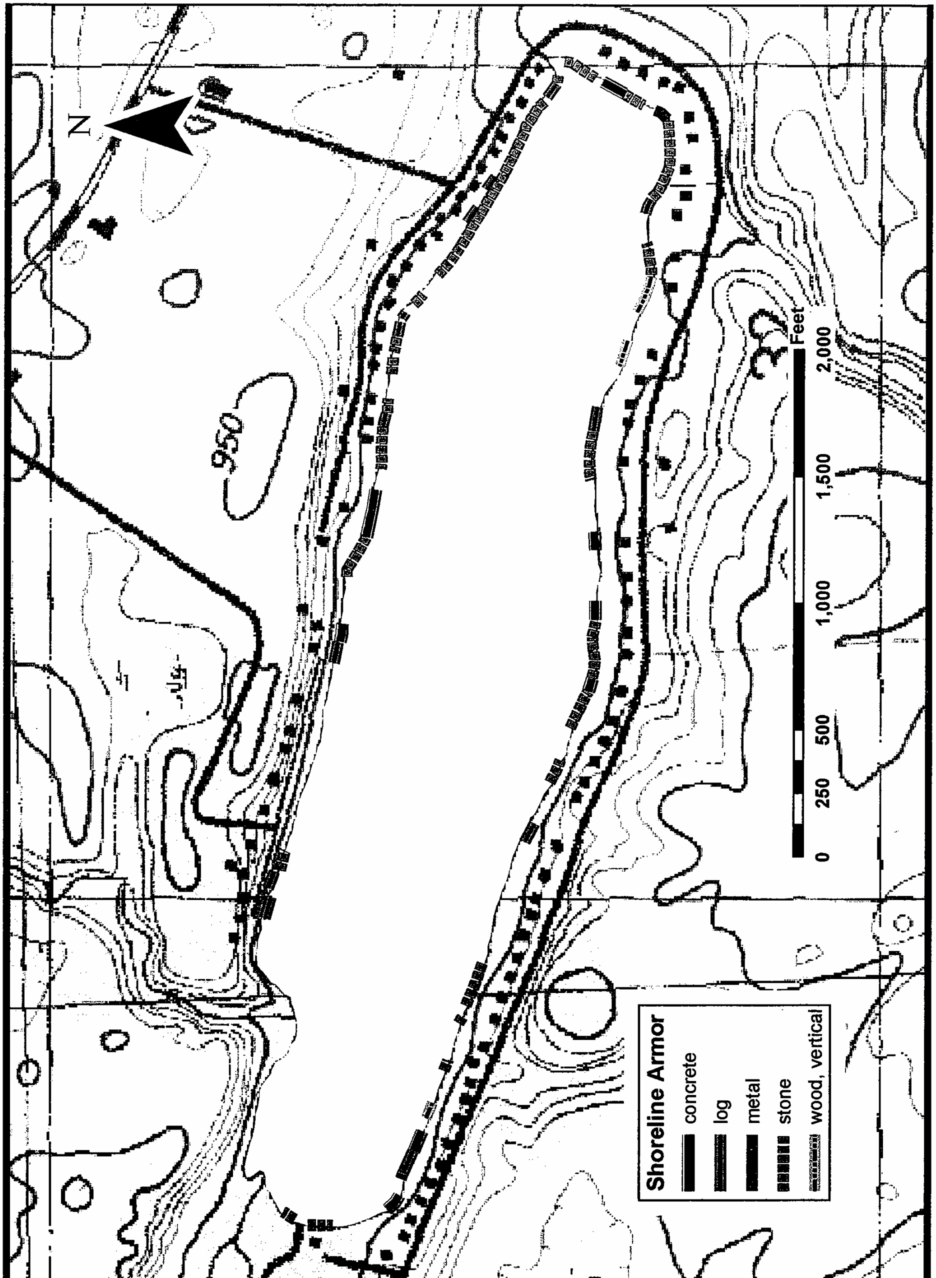


Figure 4.2 Shoreline Condition Map of Ball Lake

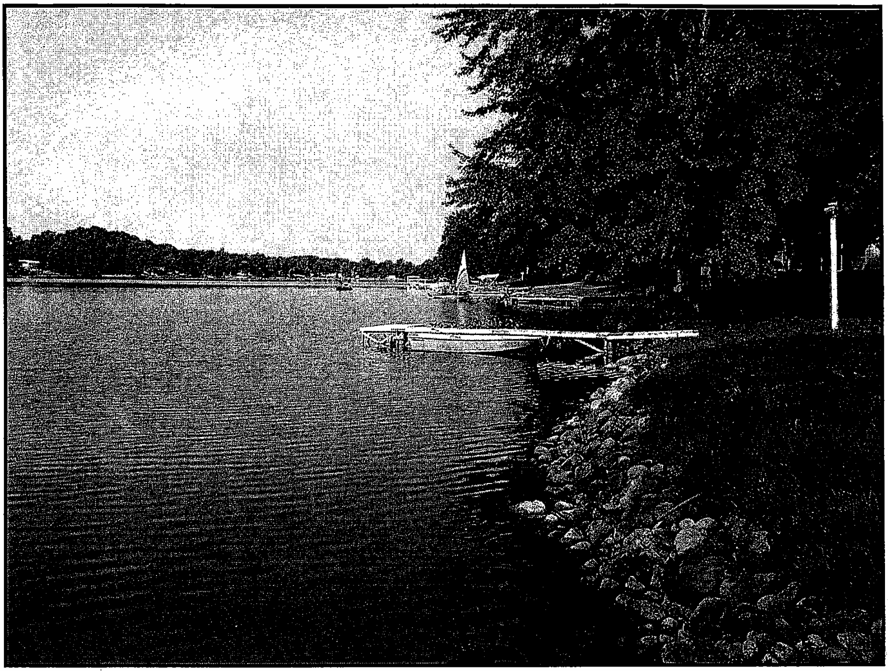


Figure 4.3 Typical Ball Lake Shoreline

FISHERIES

HISTORICAL FISHERIES SURVEYS & MANAGEMENT

A number of studies of the fisheries of Ball Lake have been conducted by IDNR Fisheries over the years beginning in 1967. In general, these studies consisted of several days of fish collection using electrofishing, gill nets, and or trap nets. The findings of these studies are summarized here in chronological order. Keep in mind that various types of equipment and varying levels of sampling effort were used for each of these studies. Fisheries management activities undertaken at Ball Lake are also presented in chronological order here.

1967 Lake Survey Report

Author: Gary Hudson
Dates: 7/31 - 8/4
Number of fish: 492
Number of species: 16

Dominant species:
- Bluegill 30.3%
- Spotted sucker 21.5%
- Yellow perch 9.6%
- Largemouth bass 8.9%

Comments:

- growth rates and condition: average
- species composition: poor
- DO & temp indicate conditions adequate to maintain holdover population of trout

Recommendations:

- Eradication (reclamation)
- stocking w/ 300 rainbow trout

1968 Fisheries Management

- Total fish eradication conducted due to size of rough fish population and abundance of 3 - 5" Bluegill – recommendation of 1967 study
- Lake restocked with smallmouth bass, rock bass, rainbow trout

Note: Total eradication of rough fish in Ball Lake was not achieved, but "a much improved fishery developed" - per Ledet 1983 report.

1969 Fisheries Study

Author: Richard Peterson
Dates: 7/28 - 7/31
Number of fish: 316
Number of species: 17

Dominant species:
- largemouth bass 36.1%
- rainbow trout 17.7%
- yellow perch 17.4%
- bluegill 7.6%
- white sucker 5.4%
- smallmouth bass 3.2 %

Comments:
- called Ball Lake oligotrophic
- rock bass off to poor start
- much improved fishery

Recommendations:
- none

1972 Fisheries Study

Author: Richard Peterson
Dates: 6/26 - 6/28
Number of fish: n/a
Number of species: n/a

Dominant species:
- bluegill 35.2%
- largemouth bass 25.6%

Comments:
- none

Recommendations:
- none

1978 Fisheries Study

Author: Richard Peterson
Dates: n/a
Number of fish: 410
Number of species: 20

Dominant species:
- largemouth bass 24%
- bluegill 23.2%
- spotted sucker 10.5%

- black crappie 8.3%

Comments:
- dominant fish by weight, spotted sucker (30.1%), carp (9.2%), largemouth bass (8.8%) and white sucker (8.3%)

Recommendations:
- none

1983 A Fish Population Survey & Survey of Fish Harvest at Ball Lake, Steuben County

Author: Neil Ledet
Dates: 9/19 - 9/22
Number of fish: 670
Number of species: 17
Dominant species:
- gizzard shad 31.8%
- largemouth bass 25.4%
- bluegill 9.4%
- black crappie 5.1%

Comments:
- gizzard shad absent in 1978
- dominant fish by weight, largemouth bass 32%, gizzard shad 19.4%, white sucker 16.6%, spotted sucker 15.4%
- largemouth growth rates above average, bluegill growth rates average
- sport fishery continued to deteriorate and was marginal for most species.
- Presence of gizzard shad and two species of sucker detrimental to fishery
- Ball Lake on per acre basis supports one of the largest largemouth bass populations of any northern Indiana lake
- NO TROUT COLLECTED, trout die-offs reported during summer of 1983, annual trout die-offs appear to be substantial.

Recommendations:

- discontinue trout stocking
- stock 10" tiger muskies at a rate of 8/acre (696 in 10/84 & 10/85)
- promote largemouth bass fishery through media

NOTE: Milfoil (*Myriophyllum spp.*) shows up in the plant survey for the first time.

1985 Fisheries Management

Initial stocking with Tiger Muskie
stocking in 1986, 1987, 1989, and 1990

1986 An Evaluation of Survival and Growth of Pellet-reared Tiger Muskellunge Stocked into Three Natural Lakes

Author: Neil Ledet
Number of fish: n/a

Dates: August
Number of species: n/a

Dominant species:
- gizzard shad 30%
- white sucker 16%

Comments:
- produced relatively few fish

Recommendations:
- none

1987 Ball Lake Spot Check Survey

Author: Neil Ledet
Number of fish: n/a

Dates: 7/1 - 7/2
Number of species: n/a

Dominant species:
- Gizzard shad 62.1%
- White sucker 12.2%
- largemouth bass 6.1%
- black bullhead 6.1%

Comments:
- Survey to evaluate the recent release of Tiger muskies

Recommendations:
- none

1988 Ball Lake Steuben County Fish Management Report

Author: Neil Ledet
Number of fish: 493

Dates: 7/11 - 7/14
Number of species: 20

Dominant species:
- gizzard shad 53.3%
- bluegill 8.5%
- largemouth bass 7.9%
- white sucker 6.3%

Comments:

- sport fishery marginal. Gizzard shad continue to dominate. Shad & sucker account for 64% of population and 55% of weight.

- "Ball Lake's water quality has declined over the years. Sediment and nutrients have entered the lake through the Fish Creek Inlet. Improved land use practices in the watershed should improve Ball Lake's water quality. Aquatic vegetation, which is limited by the steep bottom gradients and small littoral zone, is not a problem. The small littoral zone also limits the production of warm water fish."

Recommendations:

- continued stocking of muskies (700 10" per year)
- installation of two brush pile fish attractors.

1990 Tiger Muskie Management Report

Author: Neil Ledet
Number of fish: 155
Dates: 4/22 - 4/25
Number of species: 10

Dominant species:

- gizzard shad 48.4%
- yellow perch 22.6%
- black crappie 14.2%
- tiger muskie 7.1%

Comments:

- shad generally detrimental to sport fish populations, competing with small sport fish for food and space.

Recommendations:

- none

1995 Fisheries Study

This study was mentioned in other reports, although a copy of the report was not provided for review.

1996 Ball Lake Fish Harvest & Population Survey

Author: Neil Ledet & Larry Koza Dates: 7/8 - 7/10
(also creel survey April - September -- see Recreational Usage in Section 1)
Number of fish: 1042 Number of species: 21

Dominant species (dominant sport fish?):
- Bluegill 46.6%
- Black crappie 11.6%
- logperch 8 %
- largemouth bass 7.4%

Comments:
- bluegill & crappie numbers up from previous surveys
- total harvestable fish low
- with the exception of catch & release tiger muskie fishery, quality of Ball Lake fishery is marginal

Recommendations:
- none

Current Fisheries Information

Methodology

IDNR Division of Fish & Wildlife, Fisheries Section conducted a fisheries study of Ball Lake in 2001 to correspond with the Ball Lake LARE project. The study was conducted from June 11 to June 13, 2001 and consisted of 0.75 hours of eletrofishing, plus one trap net and two gill nets set for 48 hours each. A creel survey was also conducted from May through September 2001.

Results

The 2001 fisheries study yielded 992 fish representing 14 species.

Dominant species:
- Gizzard shad 77.1%
- Largemouth bass 8.2%
- Bluegill 6.1 %
- Yellow perch 4.4%

During the 2001 survey, a total of 1,636 fish were harvested. The total number of angler hours on the lake was 3,429 hours, or 39.4 hours per acre. The catch rate was 0.48 fish per hour. During 2001, 964 largemouth bass, 10 muskie and 7 tiger muskie were caught and released

At the present time, IDNR is still analyzing the data and have not produced a report with comments or recommendations.

Discussion

The fishery of Ball Lake remains marginal, primarily due to the over-abundance of gizzard shad. Despite this, the lake offers good catch and release fishing opportunity for largemouth bass and a fair opportunity for panfish. Although tiger muskellunge have been stocked in the lake annually since 1985, few of these fish are being caught.

Table 5.1
Tiger Muskie Stocking at Ball Lake

Date	Numbers	length (inches)
8/30/85	704	8.9
9/10/86	435	10.0
10/7/87	441	10.4
10/12/89	702	9.1
10/3/90	696	10.4 & 10.7
10/16/91	546	12.0
9/30/92	700	10.3
10/6/93	700	10.2
10/5/94	712	10.4
10/11/69	700	9.8
10/17/97	700	8.8
10/28/98	700	10.1
11/5/99	700	11.9
11/14/00	700	11.0
11/7/01	700	11.2

AQUATIC PLANTS

METHODOLOGY

An aquatic plant survey was conducted by inspecting the complete shoreline by boat in mid-August 2001. The location of species present were marked on a map in the field. Specimens of plants that could not be readily identified in the field were collected and placed in a cooler for later study. Aquatic plants were keyed to species wherever possible, using standard reference keys, including Manual of Aquatic Plants Second Edition (Fassett 1957), Manual of Vascular Plants (Gleason and Cronquist 1963), and Aquatic and Wetland Plants of Northeastern North America (Crow and Hellquiest 2000). No voucher specimens were prepared.

RESULTS

Field information was used to create a map of the distribution and general abundance of the aquatic plant community of Ball lake presented in Figures 6.1a and 6.1b. A macrophyte map legend and list of species present is presented in Table 6.1.

Table 6.1
Key to Aquatic Plant Distribution Map

Key	Scientific Name	Common Name
b	*Scirpus americanus*	American bulrush
C	*Ceratophyllum demersum*	Coontail
j	*Najas sp. (flexilis ?)*	Bushy pondweed (Slender water nymph)
L	*Lythrum salicaria*	Purple loosestrife
M	*Myriophyllum spicatum*	Eurasian watermilfoil
P	*Pontederia cordata*	Pickerelweed
T	*Typha*	Cattail
W	*Nymphaea tuberosa*	White water lily
Y	*Nuphar advena*	Yellow water lily
1	*Potamogeton pulcher*	Spotted pondweed
2	*Stuckenia pectinata (P. pectinatus)*	Sago pondweed

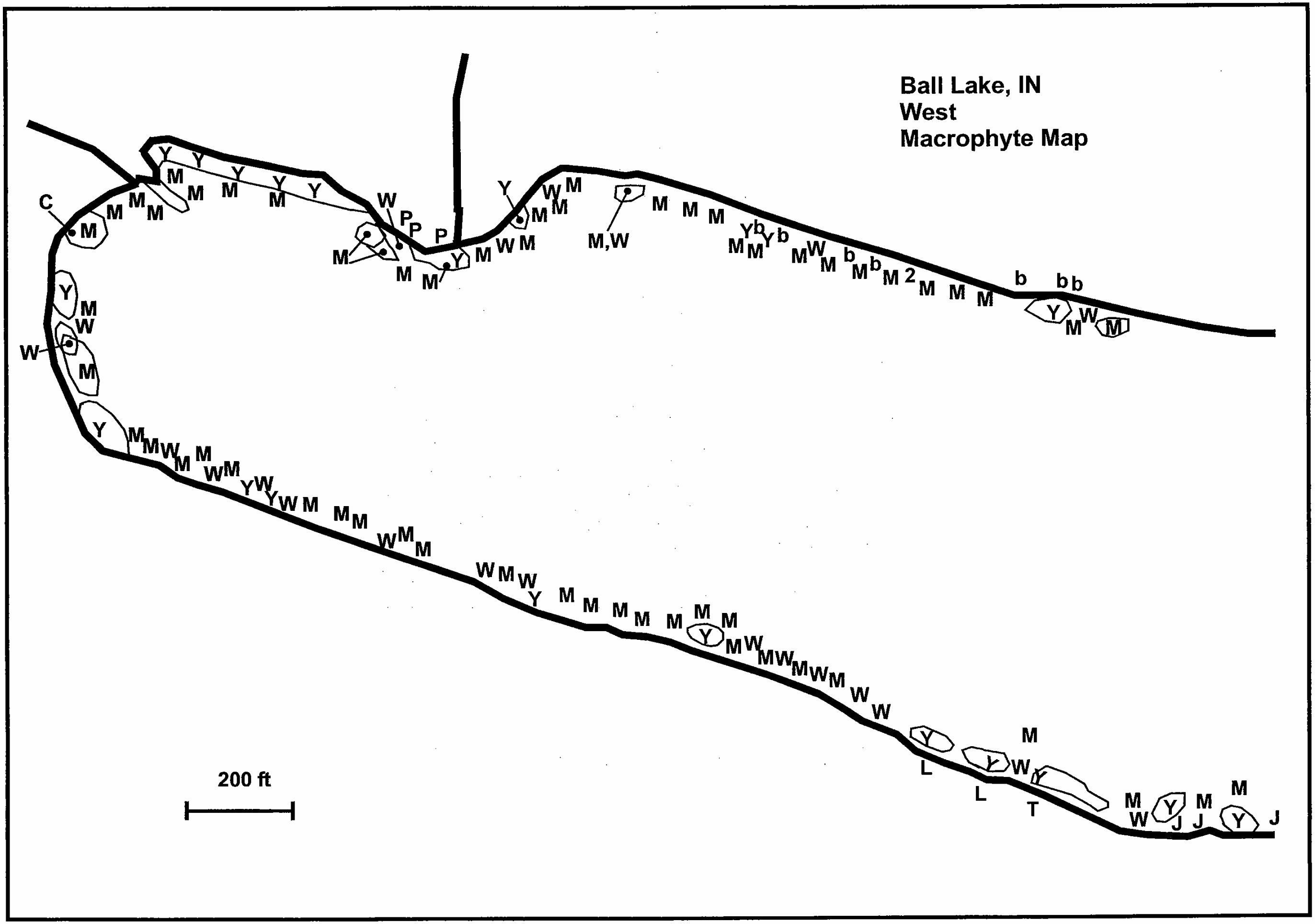


Figure 6.1a Ball Lake Macrophyte Map, west end of lake

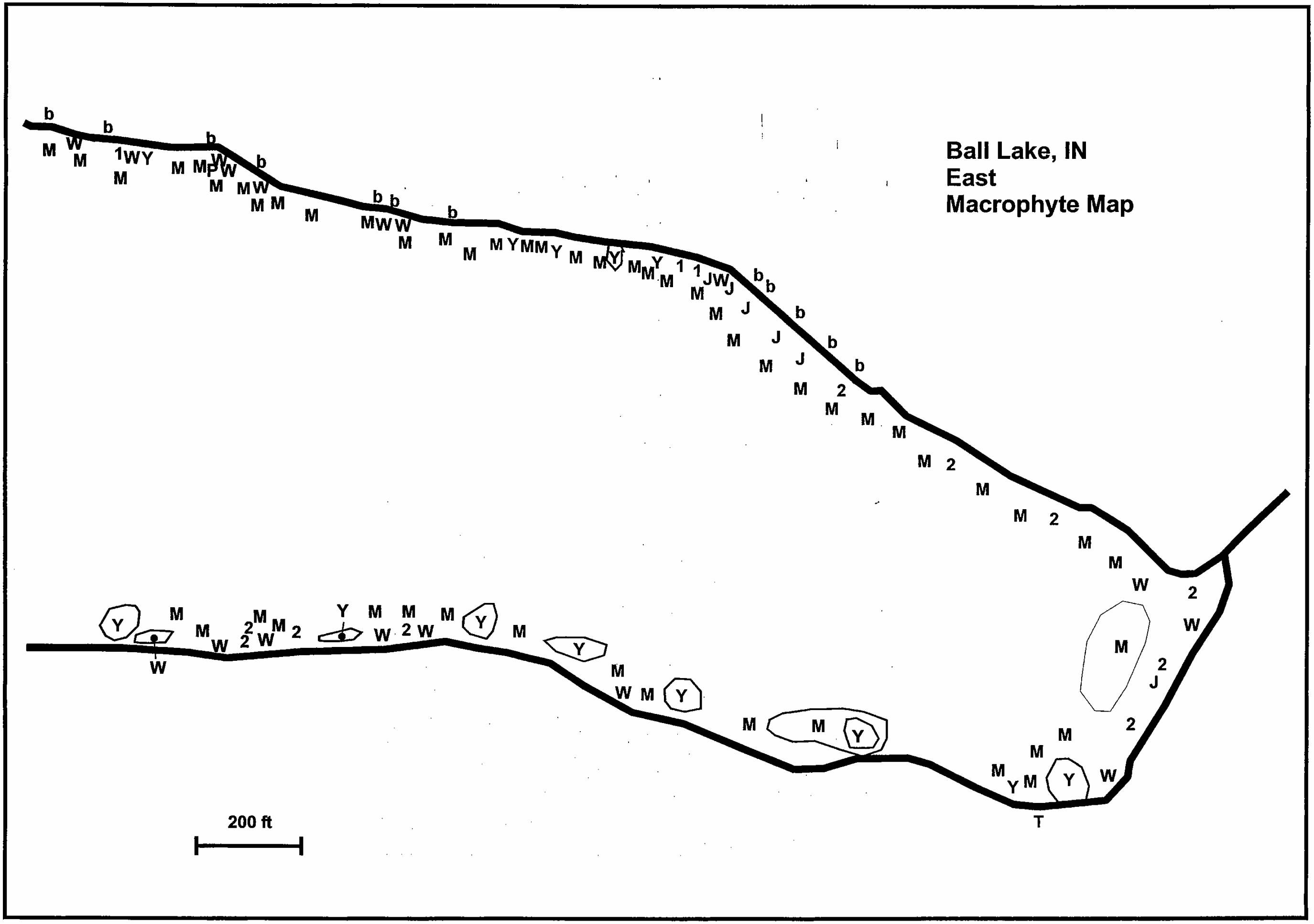


Figure 6.1b Ball Lake Macrophyte Map, east end of lake

DISCUSSION

THE AQUATIC PLANTS OF BALL LAKE

Visibility into the water was limited by phytoplankton-bloom induced turbidity during the macrophyte survey. Therefore there may have been some low-growing species that had been identified in past studies that went unobserved, such as *Chara*, *Elodea canadensis*, or several species of low-growing *Potamogetons*. Two invasive species were observed: Eurasian watermilfoil (*Myriophylum spicatum*) and purple loosestrife (*Lythrum salicaria*). One state endangered species was also present in Ball Lake: Spotted pondweed (*Potamogeton pulcher*).

Eurasian watermilfoil (*Myriophylum spicatum*) is a perennial aquatic plant that grows in depths of 5 to 20 feet of water. The plant forms dense stands with a thick canopy of branching stems at the waters surface and can interfere with boating, swimming, and fishing. This invasive species also has the potential to spread downstream since its primary method of spreading is through stem fragments. Within Ball Lake, Eurasian watermilfoil, and aquatic plants in general, were limited by the steeply sloping bathymetry around the lake shore. Water depth drops off rapidly except at inlet and outlet ends, so Eurasian watermilfoil was primarily limited to broad beds in those regions and a narrow band along the north and south shore. Unfortunately, it is nearly impossible to get a boat from shore or the launch out into the main lake without passing through the Eurasian watermilfoil stands. Eurasian watermilfoil may have been present in Ball Lake since at least 1983, when "*Myriophylum* spp." was listed in an IDNR Fisheries report.

The presence of purple loosestrife (*Lythrum salicaria*) along the shore is a concern as well. The stands observed appeared as if they may have been cultivated. This plant is an extremely aggressive wetland invader and has the potential to significantly impact the exceptional wetland habitats of the Ball Lake watershed. Purple loosestrife is a stout, erect perennial herb with a strongly developed taproot. It may grow from 3 to 10 feet tall, with an average height of 5 feet, topped by a showy spike of rose-purple flowers that are present in mid-to-late summer. Purple loosestrife occurs widely in wet habitats, such as freshwater marshes, fens, sedge meadows, and wet prairies, but it also occurs in roadside ditches, on river and streambanks, and at the edges of lakes and reservoirs. It thrives best in moist soil conditions in full sun, but it can survive in as much as 50% shade. Purple loosestrife quickly crowds out most native vegetation in marsh, fen, sedge meadow, and wet prairie communities, creating a monoculture that provides little food or shelter for native wildlife. Once established, it can destroy marshes and wet prairies and choke waterways.

The reproductive capacity of purple loosestrife is one of the most significant and relevant characteristics of this herbaceous perennial. A single stalk can produce 300,000 seeds, and densities as high as 80,000 stalks per acre have been recorded, with the potential of producing as many as 24 billion seeds per acre. The seeds can remain viable even after 20 months of submergence in water. Seed set begins in mid-to-late July and continues through late summer. Seeds may be dispersed by water, wind and in mud attached to animals. Purple loosestrife also spreads vegetatively. Root or stem segments can form new flowering stems. Muskrat cuttings and mechanical clipping can also contribute to rapid spread by floating in riverine and lacustrine systems. Purple loosestrife lacks natural enemies in the United States.

Ecological Role of Aquatic Plants

Not all aquatic plants are bad. Aquatic plants are an important part of a lake ecosystem, providing food, shelter, and breeding sites to a wide variety of aquatic and non-aquatic animals. Aquatic plants also help prevent erosion of banks and near-shore areas due to wind and wave action. When excessively abundant, aquatic plants not only detract from the recreational and aesthetic uses of a waterbody, but may actually reduce the ecological value and negatively impact the fisheries.

Types of Aquatic Plants

There are three general groups of aquatic plants: those that have erect stems and leaves and emerge out of the water, those whose leaves are primarily floating, and those with stems and leaves that are primarily submerged. Emergent plants are typically limited to wet areas and shallow waters along the shore. Cattails are typical emergent aquatic plants. Floating-leaf plants such as water lilies (*Nuphar* & *Nymphaea*) and watershield (*Brasenia*) occur from near shore regions to waters that are 3 to 4.5 meters (10 or 15 feet) deep. Water lilies are typical emergent aquatic plants. Submerged plants are variable in their habit. Some submerged plants, such as elodea, grow along the lake bottom, and may only extended 15 centimeters (6 inches) or less above the sediments. Other submerged plants, such as some milfoils (*Myriophyllum*), may grow in depths of 4.5 meters (15 feet) or more and extend to the lake's surface. Still others, such as the pondweeds (*Potamogeton*), have both submerged leaves and floating leaves.

Factors that Control Aquatic Plant Distribution and Abundance

The distribution and abundance of aquatic plants are generally limited, in order of importance, by light (a function of water clarity and depth), availability of suitable substrate, and nutrients. Submerged aquatic plants are particularly limited by light, growing out into deeper water in clear lakes and restricted to near-shore regions in less clear waters. Therefore, a long-term change in the mean depth or transparency of a lake would likely lead to a change in submerged plant cover and biomass. Aquatic plants with floating leaves are capable of growing to much greater depths, and are generally not limited by water column light availability.

Excessive external nutrient loading is not a direct cause of aquatic plant problems. In fact, higher external nutrient loading tends to reduce aquatic plant biomass due to shading associated with algal blooms. Sediment nutrient concentrations are important, however. Problematic growth of aquatic plants can be expected in lakes or ponds having shallow warm water, sediments of rich, fine-textured, moderately organic soils, and transparency greater than or equal to 2 meters (6½ feet). Plants may also be locally more abundant in areas that naturally have a more organic bottom, such as near inlets, outlets and quiet bays or in areas that receive runoff from shoreline development and septic systems.

IMPACT OF INVASIVE, NON-NATIVE SPECIES

Invasive non-native species tend to grow in dense stands, crowding out members of the native plant community. The extreme densities these exotic species can reach causes several other negative impacts on the aquatic environment. In lake systems, the fish community can be negatively impacted through loss of spawning and foraging grounds. Also, the decomposition of this extra plant material can cause oxygen stressed conditions, which can result in a fish kill. Furthermore, these plants release nutrients and increase the rate of sediment accumulation, thereby accelerating the eutrophication process. Finally, by impairing boating and swimming, fishing success, and reducing a lake's aesthetic appeal, the presence of these exotic plant species can cause economic hardships to communities which rely heavily on tourism dollars. In wetland systems, this reduction in plant biodiversity is also accompanied by a reduction in wildlife food and shelter value, causing a near total disruption of the ecosystem.

PROTECTION OF STATE ENDANGERED SPECIES

The aquatic plant survey of Ball Lake identified the presence of a state endangered species, *Potamogeton pulcher*. This plant was noted to be present in one location along the northern shore but may be present in additional portions of the lake. Any restoration efforts that may be conducted in Ball Lake to control aquatic vegetation or may have an impact on aquatic vegetation (such as dredging) should include a preliminary step to ensure that *P. pulcher* will not be impacted.

WATERSHED NPS INVESTIGATION

There are no point source discharges in the Ball Lake watershed; therefore, all pollutants enter the lake from nonpoint sources. Watershed investigations were conducted to identify potential sources of pollutants to Ball Lake.

METHODOLOGY

F. X. Browne, Inc. conducted an evaluation of the watershed to determine potential sources on nonpoint source pollutants. Specific target areas included streambanks, stream road crossings, and farms. Only sites that were easily accessible, such as along roads or within a short walking distance from a road were investigated. In an effort to identify the nonpoint source pollution problems in the Ball Lake watershed, F. X. Browne, Inc. evaluated watershed land uses and conducted field surveys throughout the watershed. Field work involved identifying eroding stream crossings, eroding stream banks, urban stormwater problem areas, active farms (livestock and crop), and additional nonpoint source problem areas. As each site was inspected, the location of the problem area was marked on a map, GPS coordinates were recorded, a sketch of the problem area was prepared, a photograph was taken, and the Best Management Practice (BMP) best suited to the problem area was identified and listed. BMPs are methods for correcting nonpoint source pollution problems that are specific to the site of the problem. BMPs were identified in the field based on treatment applicability, soil types, slopes, and other potential site constraints.

Using information gathered in the field, the locations of the problem areas were added to the GIS for the Ball Lake watershed, and a Problem Area Identification Map was developed.

RESULTS

The major sources of erosion and nonpoint source pollution problem areas in the Ball Lake watershed appear to be eroding streambanks and roadside erosion. Ditching and tiling of farm fields has allowed the farm fields and other areas to drain faster during storm events, thereby increasing the volume and peak discharge of stormwater runoff in the natural streams that drain to Ball Lake. Due to the highly erodible soils in the watershed, there are many areas of severely eroded streambanks from the high peak flows that occur during larger rain events.

Most of the agricultural land in the watershed is part of the Conservation Reserve Program (CRP), and these areas that used to be in crop production are currently being left in grass. Row crop agricultural lands, including mainly corn and soybeans, use no-till and low-till methods. The fields are most likely tilled every third year or so. In general there are buffers between row crops and ditches; however, several areas were observed with no buffers or very small buffers that should be increased. There are several dairy farms in the watershed with associated pastures. One concentrated feed lot, located at the northwest top of the watershed on Bellefountaine Road near Meridian Road, consisted of bare soils that can easily erode.

There are many pothole and other wetlands in the watershed that help to purify stormwater runoff. These areas should be protected to the maximum extent possible. Additionally, many of the ditches are very well vegetated which helps to slow down and filter stormwater runoff from farm fields.

The locations of specific problem areas that were identified as part of the field investigations are shown in Figure 7.2. With the exception of site M2, an animal feedlot, all problem areas identified in the figure are streambank erosion problems. Streambank erosion problems should be stabilized using bioengineering or structural methods, and a buffer should be maintained around the feedlot. Typical examples of streambank erosion in the Ball Lake watershed are shown in Figure 7.1 and in Figures 7.3 and 7.4.

Figure 7.1 Example of Stream Bank Erosion in Ball Lake Watershed at Site B

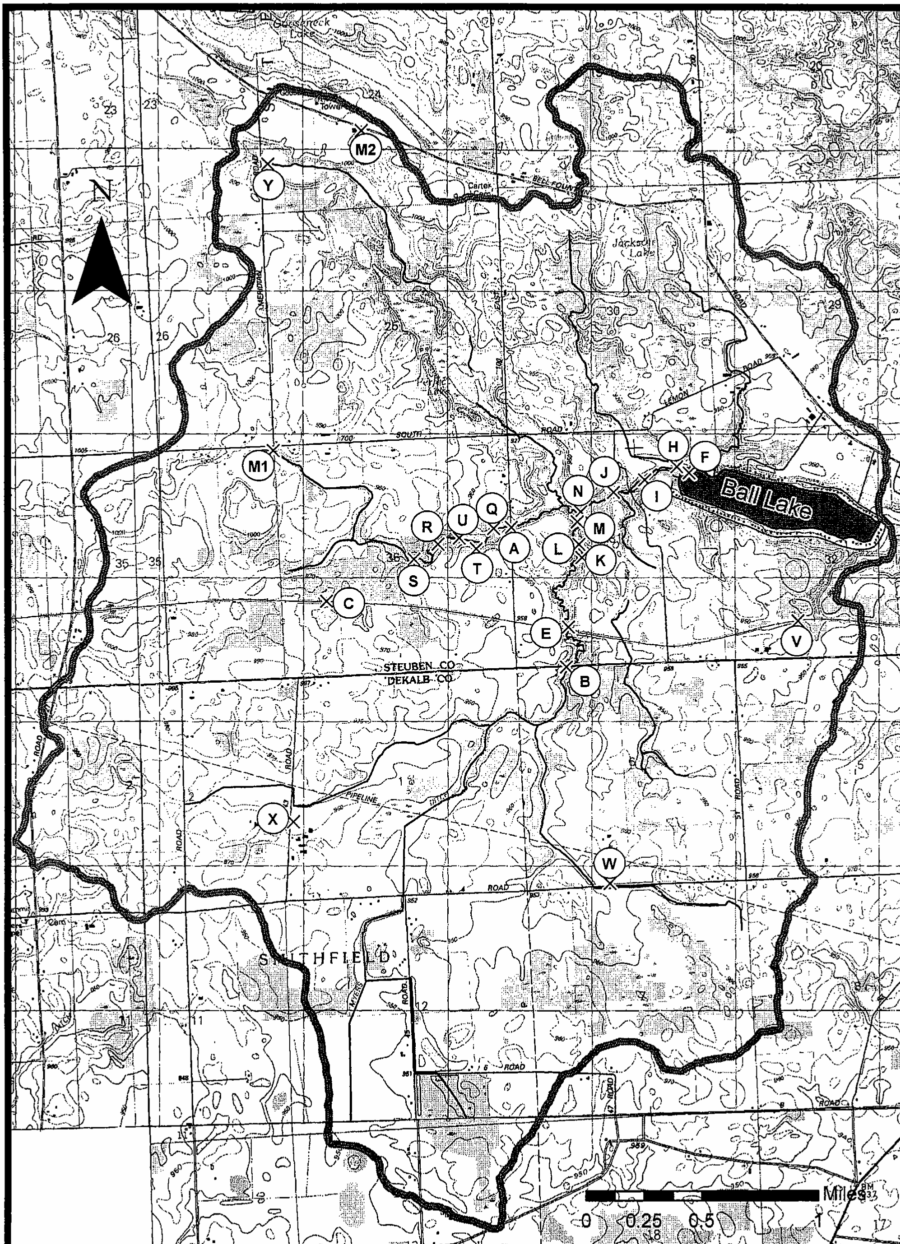


Figure 7.2 Nonpoint Source Problem Areas in the Ball Lake Watershed

Figure 7.3 Example of Stream Bank Erosion in Ball Lake Watershed at Site E

Figure 7.3 Example of Stream Bank Erosion in Ball Lake Watershed at Site I

NONPOINT SOURCE POLLUTION MODELING

HYDROLOGIC BUDGET

INTRODUCTION & METHODOLOGY

The development of a hydrologic or water budget for a lake is important in understanding the flow of pollutants through a lake and in evaluating the lake's response to those nutrients and later to any restoration techniques that might be implemented. The water budget is a balanced equation of inputs and outputs over the course of a year, and can be defined as:

Inflow + Precipitation = Outflow + Evaporation + Change in Storage

Inflows can include tributaries (streams and ditches) that drain directly to the lake, point source discharges, shoreline runoff (overland flow), and groundwater (springs and seeps). Outflows can include drainage through the lake's outlet, groundwater discharges, and water withdrawals for water supply or irrigation.

Ideally, a water budget is determined through careful and frequent measurements of inflows and outflows over the course of one or more years. In the absence of this level of monitoring data, the water budget for a lake can be estimated in several ways. The simplest method is to obtain annual discharge (stream volume) values from USGS gaging stations on nearby streams. These values can be converted to an average discharge per square mile (cfs-m) by dividing annual discharge by the station drainage area. The cfs-m value can then be multiplied by the study watershed area in square miles to get an estimated total discharge (water volume) for that watershed. There are three USGS stream gaging stations near the Ball Lake watershed that have a relatively long period of record. The closest of these is Station 01477720 Fish Creek at Hamilton located about 2 miles downstream of the outlet of Ball Lake. This station has been operational since 1970 and has an average annual discharge over that period of 34.19 cfs (range: 17.9 - 54.9 cfs). The drainage area at Station 01477720 is 37.5 square miles, yielding an areal discharge of 0.91 cfs-m (range: 0.48 - 1.46 cfs-m). The other two stations, 04099540 Pigeon Creek near Angola and 04179500 Cedar Creek at Auburn, are located eight and ten miles away from the nearest point of the Ball Lake watershed, respectively. The cfs-m for the Pigeon Creek station was 1.01(range: 0.23 - 2.01 cfs-m). The cfs-m for the Cedar Creek station was 0.78 (range: 0.28 - 1.87 cfs-m).

Alternatively, the total water inflow to a lake in a year can be estimated by adding together the annual expected runoff, precipitation and evaporation for the area (Dillon 1975). Typically, values for average annual runoff, precipitation and evaporation are estimated from the 1970 National Atlas of the United States of America (USGS 1970). Sometimes more accurate regional estimates are available. For instance, the values for average runoff and precipitation for northern Indiana can be estimated from a map by Lloyd and Lyke (1995). The formula for converting these numbers into a water budget (total inflow volume to lake) is:

$A_d \bullet r + A_0 \bullet (P_r - E_v)$,

where A_d = watershed area (m^2, minus lake area), r = average annual runoff (m/yr), A_0 = lake surface area (m2), P_r = average annual precipitation (m/yr), and E_v = average annual lake evaporation (m/yr).

BALL LAKE HYDROLOGIC BUDGET

The hydrologic budget for Ball Lake was calculated based upon Dillon (1975) methodology using best available estimates for annual runoff, precipitation and evaporation. Using the sources mentioned above, the following water estimates were derived:

Average annual runoff: 0.28 m (11 in.)[5]
Average annual precipitation: 0.91 m (36 in.)[4]
Average annual evaporation: 1.016 m (40 in.)[6]

These parameters were fed into a computer program (Martin 1994) along with the bathymetric information on the lake and used to calculate the hydrologic budget for Ball Lake. Based on these calculations, Ball Lake has:

Flushing rate: 2.0 times per year
Residence time: 0.5 years
Areal water load: 24.7 meters/year
Average Annual water inflow: 8,472,585 m^3
Phosphorus retention coefficient: 0.45

For comparison, the hydrologic budget was also calculated for Ball Lake using the cfs-m value from Fish Creek (0.91 cfs-m) and the area of the Ball Lake watershed (11.9 mi2). The result is an annual discharge at Ball Lake of 10.83 cfs and therefore an average annual water inflow of 9,670,294 m^3. The flow at the Cedar Creek may better approximate conditions in the Ball Lake watershed. Calculations using the Cedar Creek cfs-m of 0.78 yields a Ball Lake annual discharge of 9.282 cfs and an average annual water inflow of 8,228,827 m^3, very similar to the estimate based upon runoff, precipitation and evaporation.

[5] Lloyd and Lyke 1995

[6] USGS 1970

POLLUTANT BUDGETS

INTRODUCTION & METHODOLOGY

The pollutant budgets for a lake are similar to the hydrologic budget in that they are calculated by balancing inputs and outputs to the waterbody. A pollutant budget can be summarized as:

external load = outflow + sedimentation - internal load + change in storage

Developing a pollutant budget based on such a mass balance equation requires a considerable amount of watershed monitoring and is beyond the scope of LARE program studies. However, these budgets can also be estimated by using land use information for a given watershed and literature values of expected pollutant contributions for each of the various land uses. These values are called export coefficients and describe the amount of a pollutant contributed for a given area of land use. The Ball Lake nitrogen and phosphorus budgets were calculated using this methodology. Land use categories were combined into more general groups and export coefficients were selected as the low end values presented in Reckhow (1980) since these might best represent conditions found in northern Indiana. Low values were chosen since agricultural management practices in the Ball Lake watershed are generally very good and have improved considerably since the 1970s and 1980s when these export coefficients were first collected. Since the homes around Ball Lake are served by sanitary sewer and there are no known point source discharges in the watershed, it was assumed that wastewater impacts are a negligible component of the nitrogen and phosphorus budgets.

Suspended solids loadings were calculated using the land use export coefficients from Holdren et al (2001). The lowest values for suspended solids were selected since there is no good basis for selecting an intermediate value from within the ranges provided by this publication. This may underestimate the sediment loadings in the Ball Lake watershed, however, since the watershed contains a large percentage of highly erodible soils and there is a fair amount of streambank erosion that takes place during high flow periods.

BALL LAKE POLLUTANT BUDGETS

PHOSPHORUS & NITROGEN

Results of the nutrient budget calculations are presented in Table 8.1. Ball Lake receives an estimated annual phosphorus load of 1,624 kg and an estimated annual nitrogen load of 11,422 kg.

Table 8.1 Phosphorus & Nitrogen Budget Calculations for Ball Lake Watershed					
Land Use	Area (ha)	Loading Coefficients (kg/ha/yr)		Annual Load (kg/yr)	
		TP	TN	TP	TN
Water	80.26	0.00	0.00	0.0	0.0
Pasture & Hay	436.01	0.37	4.27	162.4	1,862.8
Row Crops	2,015.76	0.70	3.99	1,411.0	8,032.8
Forest	540.29	0.07	2.00	37.2	1,080.6
Residential	6.93	0.50	4.34	3.5	30.0
Precipitation	34.30	0.28	12.12	9.7	415.9
TOTAL NUTRIENT LOADS				1,623.6	11,422.1

SUSPENDED SOLIDS

Results of these calculations are presented in Table 8.2. Ball Lake receives an estimated suspended solids load of 58,231 kg.

Table 8.2 Suspended Solids Budget Calculations for Ball Lake Watershed			
Land Use	Area (ha)	Loading Coefficients (kg/ha/yr)	Annual Load (kg/yr)
		TSS	TSS
Water	80.26	0.00	0.0
Pasture & Hay	436.01	30.00	13,080.3
Row Crops	2,015.76	20.00	40,315.3
Forest	540.29	1.00	540.3
Residential	6.93	620.00	4,295.3
Precipitation	34.30	0.00	0.0
TOTAL SUSPENDED SOLIDS LOAD			58,231.2

Waterfowl Loading

The waterfowl survey data were used to estimate the potential phosphorus contribution attributable to an established population of waterfowl. For this calculation, the maximum number of geese and ducks observed at any time were assumed to be living on the lake year-round. Loadings were calculated using the program Goose (Martin 1997), which uses the methodology of Grimillion and Malone (1996). Similarly to calculating nutrient loading from septic systems, the calculation is based on the amount of time waterfowl spend on the lake (duck use days) and the amount of phosphorus that duck and goose waste contributes to an area in a day. The program could also be used with a mix of resident and seasonal waterfowl, but there was insufficient data to determine whether the birds were resident or visitor. Based on the waterfowl survey data, Ball Lake had a maximum of 48 ducks and 42 geese in residence. If these waterfowl remained on the lake year-round in similar numbers (worst-case scenario), they would contribute 16.8 kg of phosphorus to the nutrient budget in a year, or roughly 1 percent of the total phosphorus loading from the watershed. It is not likely that these waterfowl are year-round residents, and the survey data showed that the number of waterfowl on the lake fluctuated considerably during the day and at different times of the year. Therefore, waterfowl are not a major source of phosphorus loading to Ball Lake.

Water Quality Modeling

A number of empirical water quality models have been developed to predict in-lake phosphorus concentrations based upon lake morphology and watershed phosphorus loading. Several of these models were used to check on how well the calculated phosphorus budget developed using the UAL method would predict measured in-lake phosphorus. All of the models gave similar results. For example, Dillon (1975) developed a model that can be expressed as:

$$TP = L(1-R)/pz$$

where:

- TP = mean in-lake total phosphorus concentration
- L = areal phosphorus load
- R = the phosphorus retention coefficient
- p = flushing rate, and
- z = mean depth

Based on the input parameters specific to Ball Lake, this model predicts a mean phosphorus concentration of 0.107 mg/L. Sixteen other empirical models were also used to estimate Ball Lake phosphorus based upon the phosphorus budget, yielding phosphorus concentrations that ranged from 0.078 mg/L to 0.258 mg/L, with a mean of 0.134 mg/L. Not all of these models are appropriate to the Ball Lake system (for example, may over- or under-estimate phosphorus in lakes with Ball Lake's morphology or were designed specifically for large reservoirs). Of those models deemed appropriate for Ball Lake, the Dillon (1975) equation was selected as the representative model for its ease of use and similarity in results to the others.

Based upon the phosphorus model, the phosphorus budget predicts that the mean phosphorus concentration should be about 2.1 times higher than the measured[7] weighted phosphorus concentration of 0.051 mg/L and 1.5 times higher than the measured numerical average of 0.071 mg/L. It is believed that the Ball Lake measured phosphorus values were naturally lower than predicted since the Ball Lake watershed had experienced relatively dry conditions prior to and during the sampling period, and so therefore had experienced lower than normal phosphorus loading prior to sample collection. Field measurements measure the effect of actual loading while the UAL model predicts annual average loading under normal conditions.

This can be further checked by estimating actual loading to the lake in 2001 by multiplying the estimated water inflow from the hydrologic budget by the average of measured instream phosphorus concentrations. This calculation yields an annual phosphorus load in 2001 of 799.8 kg, which yields a predicted inlake phosphorus concentration of 0.053 mg/L when plugged into the Dillon model. Therefore, the phosphorus budget is believed to be representative of actual conditions for the Ball Lake watershed.

A phosphorus model can also be used to predict the amount of phosphorus reductions needed to achieve a given in-lake phosphorus concentration. The model equation can be rearranged to predict a loading based upon a desired in-lake phosphorus concentration. The difference between the estimated loading of 1,624 kg P/year and predicted loading can be expressed as a percent. This value is the percent reduction necessary to achieve a desired in-lake phosphorus concentration. For Ball Lake, a 52 percent reduction in watershed phosphorus loading would be necessary to achieve the existing measured mean in-lake phosphorus concentration. This load reduction estimate is probably low since the actual load to Ball Lake in 2001 was lower than normal as a result of low rainfall earlier in the year. In order to achieve improved water quality, a 63 percent reduction in watershed phosphorus loading would be required to achieve an mean in-lake phosphorus concentration of 0.040 mg/L, while a 72 percent reduction would result in a mean in-lake phosphorus concentration of 0.030 mg/L.

The median in-lake phosphorus concentration of Ball Lake could be reduced considerably by eliminating the internal phosphorus recycling that is occurring in the hypolimnion.

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[7]from August 2001 lake sampling

INSTITUTIONAL RESOURCES

EXISTING INSTITUTIONAL RESOURCES

There are a number of institutional resources available to assist in the implementation of a Ball Lake Lake & Watershed Management Program. In addition to the institutions listed below, there may be private, not-for-profit, and environmental groups that can assist in preserving and protecting the valuable resources of the Ball Lake watershed.

AGRICULTURE, SOILS, & LAND MANAGEMENT

Sherman Liechty
Natural Resource Conservation Service
Peachtree Plaza 200
Angola, IN 46073
(260) 665-3511

DeKalb County Planning Commission
301 South Union Street
Auburn, IN 46706-2351
(260) 925-1923

Sarah Reyman, Natural Resource Coordinator
DeKalb County Soil & Water Conservation District
942 West 15th Street
Auburn, IN 467066
(260) 925-5620 ext. 3

Steuben County Planning Commission
317 South Wayne Street
Angola, IN 46703-1958
(260) 668-1000 ext. 1600

Barbara Angel
Steuben County Soil & Water Conservation District
1220 North 200 West
Angola, IN 46073
(260) 665-3511 ext. 3

Jerome Daugherty, IDNR Resource Specialist
100 East Park Drive
Albion, IN 46701
(260) 636-7682

Farm Service Agency Service Center Office
Tom Saggars, Executive Director
Angola Service Center
Peachtree Plaza 200
Angola, IN 46703
(260) 665-3211

Farm Service Agency Service Center Office
Jeff Beerbower, Executive Director
Auburn Service Center
942 W 15th St
Auburn, IN 46706-2031
(260) 925-3710

WETLANDS & WILDLIFE

US Fish & Wildlife Service
Bloomington Field Offices
620 South Walker Street
Bloomington, IN 47403-2121
(812) 334-4261

Al Van Hoey, IDNR District Wildlife Biologist
Pigeon River Fish & Wildlife Area
8310 East 300 North, Box 71
Mongo, IN 46771
(260) 367-2164

Neil Ledet, Regional Fisheries Biologist
Fawn River State Fish Hatchery
6889 North State Road 327
Orland, IN 46776
(260) 829-6241

WATER QUALITY

Indiana Lake Management Society
207 South Wayne Street, Suite B
Angola, IN 46703

Steuben County Health Department
317 South Wayne Street Ste 3A
Angola, IN 46703-1938
(260) 668-1000

Jill Hoffman, Aquatic Biologist
LARE Program Coordinator
IDNR Division of Soil Conservation
402 W. Washington St., Rm. 26
Indianapolis, IN 46206
(317) 233-5468

Carol M. Newhouse, Lakes Coordinator
IDEM Office of Water Management
Assessment Branch, Biological Studies Section
100 North Senate Avenue
PO Box 6015
Indianapolis, IN 46206-6015
(317) 308-3217

RECREATION

Division of Outdoor Recreation
Department of Natural Resources
402 West Washington
Indianapolis, IN 46204
Tel: 317-232-4020

LAKE AND WATERSHED MANAGEMENT RECOMMENDATIONS

GENERAL ISSUES

Since the Ball Lake watershed contains a diversity of valuable habitat, habitat surveys would have to be conducted prior to initiating any project that may potentially impact suitable habitat for rare, threatened or endangered species. This would include surveys of forest habitats for the presence of the Indiana bat, stream habitats for the presence of the three mussel species (white cat's paw pearly, clubshell, and northern riffleshell) and any fish population, and wetland habitats for the presence of the northern copperbelly water snake.

The in-lake and watershed management recommendations provided in the following sections are arranged in priority order based upon the ease of implementation, relative cost, and potential benefit.

IN-LAKE MANAGEMENT RECOMMENDATIONS

RECOMMENDATION ONE - MAINTAIN/IMPROVE ON NATURALIZED SHORELINE

Ball Lake is fairly unique in that its shoreline has not been lined with bulkheads and there are still many areas with relatively natural shoreline. Lakeshore residents should be encouraged to use naturalized and bio-engineered solutions where shoreline erosion becomes a problem. A vegetated buffer of low-growing native plants and shrubs along the shore will filter shoreline runoff, providing water quality benefits to the lake and improving the aesthetics of the shore. Native aquatic plants should be allowed to grow in the water along the shore's edge. Access paths to the lake to get to docks and swimming areas should be curved so as not to run directly downhill to the water.

RECOMMENDATION TWO - CONTROL OF INVASIVE PLANTS

EURASIAN WATERMILFOIL

There are a number of control methods for Eurasian watermilfoil, including mechanical and chemical means. Since the potential habitat for this plant is limited in Ball Lake due to the steeply sloping near-shore region, whole-lake chemical control is probably not warranted. In fact, unless boat access to deeper waters becomes impaired, no control method is necessary at this time. If plant densities become so thick that boating is impaired, then landowners can use several techniques to create boating lanes for lake access. A landowner may physically, mechanically or chemically remove plants from in front of their property without a permit providing the area does not exceed 625 square feet with no more than 25 linear feet along the shore and in water depths less than 6 feet. Where Eurasian milfoil grows in depths greater than six feet, a permit from IDNR would be required to create open boating lanes. In addition to chemical control, benthic mats could be used to create these boating lanes out into deeper water. These mats could be anchored in place with bent steel rods inserted into sediments in front of homes where a boat access is needed.

Large signs should be designed and placed at the boat launch to warn lake users about the presence and Eurasian watermilfoil and to provide precautions for preventing its spread into other water bodies.

Purple Loosestrife

Purple loosestrife (Lythrum salicaria) needs to be eliminated from the shores of Ball Lake before it infests the valuable wetlands of the watershed. Young plants or isolated individuals can be pulled up. This should be done prior to the plant flowering, so seeds are not spread. The plant material should be burned to prevent spread by fragmentation. Alternatively, a systemic herbicide may be applied according to directions and applicable laws. A detailed discussion of control methods is provided in the Watershed Recommendations section.

Recommendation Three - Hypolimnetic Oxygenation

A feasibility study should be initiated for restoring the oxygen to the hypolimnion of Ball Lake. The goal of hypolimnetic oxygenation would be to eliminate internal recycling of phosphorus while restoring habitat for the restoration of a coldwater fishery in the lake. It is recommended that an oxygen system rather than an aeration system be considered for Ball Lake due to its much lower capital cost and lower operational and maintenance costs. In addition, an oxygenation system designed to use compressed oxygen has a smaller facility requirement and is essentially noise-free, which are important considerations on a developed residential lake such as Ball Lake.

Dredging, which might be considered to remove phosphorus-rich sediments, would be cost prohibitive (at least several million dollars), if not technically unfeasible, due to the depth of Ball Lake (60 feet) and the thickness of the sediments, estimated to be at least 11 feet thick in the deeper portion of the lake. Dredging would not restore oxygen to the cold-water habitat. The use of aluminum salts to seal the sediments would prevent phosphorus release and would be more cost-effective (perhaps $100,000). The length of the effectiveness of this treatment would be limited if watershed controls are not already in place. This technique is also not likely to restore oxygen to the cold-water habitat.

The purpose of the feasibility study is to determine the exact sizing needed and costs for installing and operating a hypolimnetic oxygenation system in Ball Lake. The major component for the feasibility study is the collection of frequent (at least weekly) dissolved oxygen and temperature profile data from early spring until the lake becomes well-stratified. The feasibility study would also include an analysis of the anoxic volume in Ball Lake, an evaluation of installation locations for equipment, design of a system, and development of capital and operating costs.

Description of Alternatives

Hypolimnetic aeration is the introduction of oxygen into the hypolimnion of a stratified water body in order to prevent anoxic conditions from developing and, typically, while maintaining thermal stratification. As a result, the redox potential at the sediment-water interface can be maintained at a level that prevents the mobilization of phosphorus, metals and other molecules from the sediments. Simply put, these restoration technique increases the oxygen concentration in a lake's cool bottom waters without mixing the lake in the process. Oxygen in the bottom waters of lake prevents phosphorus from migrating out of the sediments and into a lake's upper waters, where it may cause algae blooms. Also, cold water fish require well-oxygenated water to survive.

The earliest record of hypolimnetic aeration is reported to be Lake Bret in the 1940s (Mercier and Perret 1949), when "water was pumped to the shore, sprayed in the air, collected and returned to the hypolimnion" (Dunst et al. 1974 via pers. comm. G. Nurnberg 2001). Since that time, a number of technologies have been developed to deliver oxygen within the hypolimnion of a lake without disturbing stratification.

There are two main technologies that can be used to aerate the hypolimnion. The first is the use of lift aerators. Lift aerators, either partial or full-lift, function by injecting air into a chamber within the hypolimnion. Rotary screw compressors are typically used to move compressed air into the system. Hypolimnetic water is pulled into the chamber by the rising air bubbles, where atmospheric oxygen dissolves into the water. After the removal of bubbles, aerated water is discharged back into the hypolimnion, thus preventing any destratification. Most air compressors are oil lubricated and release a small quantity of oil into the compressed air. All oil should be removed before it reaches the aerator as oil contamination of air bubbles inhibits oxygen transfer at the air-water interface and reduces overall transfer efficiency (Lorenzen & Fast 1997).

An alternative to lift aerators is the use of pure oxygen within mixing chambers or distributed via diffusers. Aeration with pure oxygen is more efficient than using atmospheric oxygen since the atmosphere contains only about 21 percent oxygen. Oxygenation results in higher hypolimnetic dissolved oxygen levels, lower levels of induced oxygen demand, and maintenance of more stable thermal stratification (Beutel & Horne 1999). Pure oxygen can be obtained in two ways: the use of liquid oxygen delivered in tanks, or by using on-site oxygen generators (Pressure Swing Adsorption or PSA Units) to pull O2 from the atmosphere. A hybrid technology is to use enhanced air, where an oxygen generator is used to boost O2 concentrations to about 40 percent. Pure oxygen can also be delivered to the lake in two ways: first, through the use of conventional compartment aerators (lift aerators), and second, through the use of micro-bubble diffusers. Micro-bubble diffusers generate tiny gas bubbles near the lake bottom. The gas bubbles are allowed to travel to the lake surface unencumbered by enclosures. Oxygen transfer is efficient where the bubble diameter is small and depths are greater than 10 meters (Babin, et al. 1999).

Pure oxygen systems have been refined in recent years and many of the issues associated with their use have been resolved (Horne pers. comm). Some of those issues include cost (typically equivalent to lift aerators), biofouling of aerator ports (not any more likely than with compressed air systems), and potential destratification (in most cases, microbubbles would be fully dissolved prior to disruption of thermal stratification).

Layer aeration is a patented process developed by Dr. Bob Kortmann. The process is similar to standard lift aeration, but the aerators are designed to create aerobic, cool, isothermal layers bounded by several functional thermoclines. Unlike standard hypolimnetic aeration, this process avoids nitrogen supersaturation and increased eddy diffusion across thermocline. Layer aeration redistributes available dissolved oxygen and supplements it with outside air to meet metabolic needs of layer. The system can be designed to target a "habitat" layer just below thermocline rather than trying to restore oxygen to the entire hypolimnion. This system can be designed to use either compressed air or liquid oxygen.

Oxygen Depletion Rates/Oxygen Demand

Sizing of an aeration system is critical and should take into account the increase in oxygen demand that often occurs after aeration has been implemented (Lorenzen & Fast 1977, Holland and Tate 1984). This increased oxygen consumption rate is caused by an increase in the volume of the hypolimnion, increased oxidation of organic material in the sediments and water column (Ashley 1983), increased inorganic oxygen demand (Soltero et al 1994), and increased bacterial respiration in response to aeration (ibid).

Development of accurate oxygen depletion rates and oxygen demand are important for the successful design of an oxygen restoration technology. Oxygen depletion rates are determined by calculating the loss of oxygen mass within the hypolimnion over time. Dissolved oxygen profiles throughout the growing season are used together with lake volume estimates to determine the amount, or mass, of oxygen in the hypolimnion on each sample date. The loss of oxygen mass between sample dates is plotted and regressed against time to develop the rate. The oxygen demand is then calculated as the depletion rate times hypolimnetic volume. In order to complete this calculation for Ball Lake, dissolved oxygen and temperature profiles would need to be conducted on at least a weekly basis from the spring, prior to onset of stratification, until late summer when the lake's hypolimnion well after the lake hypolimnion had become essentially anoxic.

Project Benefits

Restoring dissolved oxygen to the hypolimnion (cold bottom water) of Ball Lake would provide two lake benefits. The primary benefit is that phosphorus release from the sediments would be curtailed, resulting in a considerable reduction in the amount of phosphorus available within the lake for the growth of algae. Presently, phosphorus released from the sediments accumulates in the hypolimnion during the summer months, some of which is likely to migrate up into the warm surface waters where it provides nutrients for the growth of algae.

The second benefit to restoring dissolved oxygen in the hypolimnion is that cold-water habitat would also be restored. Presently, the lack of oxygen in the bottom waters during the summer months limits the available habitat in Ball Lake for fish that require cold, well-oxygenated water.

Once an aeration system is installed, benefits begin immediately. Many of these systems have been in operation for decades.

Potential Environmental Impacts

The various types of aeration have been used in numerous lakes. Researchers typically investigate the physical and chemical effects of aeration, but few studies have been conducted on the biological effects. Those that have studied biological effects have generally found no detrimental changes.

Amisk Lake is one case study where a considerable amount of study was conducted on the biological effects of hypolimnetic aeration. In this lake, hypolimnetic oxygenation (liquid oxygen) was used to maintain a dissolved oxygen level greater than or equal to 1 mg/L. Macroinvertebrate diversity decreased as oxygenation progressed. Chironomus abundance increased in the profundal region, possibly due to increased food potential (Dinsmore & Prepas 1997a; ibid. 1997b). Field and Prepas (1997) found no apparent treatment effects on biomass, abundance or distribution of zooplankton in the epilimnion. Daphnia abundance increased in hypolimnion, other cladocerons found at deeper depths, and diurnal vertical migration of zooplankton occurred.

Doke et al. (1995) found that in a mesotrophic lake receiving alum treatment followed by hypolimnetic oxygenation, merobenthic chaoborids experienced 90 percent decline following oxygenation. This decline was attributed to increased predation. Benthic chironomids and oligochaetes benefitted from increased dissolved oxygen and reached maximum density after oxygenation began.

Several researchers have studied changes in phytoplankton communities resulting from hypolimnetic aeration. Steinberg & Arzet (1984) found that internal fertilization of the epilimnion due to increased eddy diffusion of nutrients across the thermocline resulted in increased biomass of filamentous cyanobacteria. Webb et al. (1997) found that, in Amisk Lake, year-round oxygenation lengthened the spring diatom bloom, and delayed and reduced the severity of cyanobacteria blooms.

Additional Considerations

Siting of on-shore and in-lake components of a hypolimnetic oxygenation system brings up several considerations beyond environmental impacts. Those systems that require compressors or oxygen generation equipment generally need three phase power. Compressors would need to operate 24 hours a day, and although they can be outfitted with sound shields and housed in a sound-proofed building, there will be some noise associated with their operation. Compressors equipped with sound enclosures generally produce a sound level of about 75 dba. This noise level would be further reduced by a sound-insulated storage building. A building would need to be constructed to house compressors or oxygen generators. In a pure air (LOX) system, a concrete slab would have to be poured to support a LOX tank and a tanker truck would have to come on a regular basis to refill the onshore tank.

In-lake considerations are primarily associated with air vents that may protrude to the surface of the lake, causing a hazard to boating. Most systems have submersed vents to avoid this problem. Air/oxygen supply lines must be routed from the shore facility to the in-lake unit(s), which necessitates some burial on shore and anchoring in the lake. The supply lines are buoyant during unit operation and are therefore typically weighted down. These can be accidentally snagged by boat anchors.

Implementation Costs

The cost for hypolimnetic oxygenation are two-fold: capital costs for the purchase and installation of the equipment, and operating costs for the annual expense of electricity and liquid oxygen. These costs are specific to each lake application, since the sizing of the equipment is dependent upon the oxygen depletion rate and treatment volume specific to each lake. However, a general estimate of capital costs can be made from per acre costs associated with projects throughout the United States. For Ball Lake, the estimated capital cost would range from $90,000 to $270,000, with the lower end representing the use of a liquid oxygen system and the higher end representing compressor-driven aerators. Annual operating costs are more difficult to obtain, but might be on the order of $35,000 to $50,000 for either electricity (compressor driven aeration) or liquid oxygen.

Watershed Management Recommendations

The priority subwatershed for implementation is Myers Ditch (Station 4), followed by Cameron Ditch (Station 3). Where appropriate, these subwatersheds should be targeted first for land management practices. However, the entire Ball Lake watershed consists of highly erodible soils, and lake water quality is being degraded by nutrients, therefore no opportunity should be passed up to control nutrients or erosion in any part of the watershed.

Recommendation One - Pesticide/Herbicide Screening in Tributaries

Streams in the Ball Lake watershed should be sampled for pesticide/herbicide screening to determine whether or not a pesticide/herbicide pollution problem exists within the watershed.

Recommendation Two - Land Stewardship

Agricultural Best Management Practices

Maintain CRP enrollment

CRP enrollments within the Ball Lake watershed will begin expiring over the next few years, resulting in increased row-cropping and runoff of soil and nutrients. The NRCS and County SWCDs should work with the farmers to re-enroll these acres in CRP or some other program that will continue to provide the water quality benefits of continuous cover. This is a key agricultural BMP that will undoubtedly provide the most benefit to the future water quality of Ball Lake.

Increase Use of Buffers

Vegetated buffers along stream and ditch channels serve to filter out sediments and nutrients in overland runoff. County agencies should work with the farmers to institute grassed buffers along all waterways in the watershed. A minimum buffer width of 25 feet as measured from the top of bank is recommended. However, greater buffer widths provide both increased filtration and wildlife habitat benefit. Additionally, an evaluation of tile inlets should be conducted to assess the use of vegetative buffers around these facilities. SWCDs should work with the farmers to ensure a good buffer around all tile inlets.

Maintain Vegetation in Ditches

A number of the ditches in the Ball Lake watershed are heavily vegetated. Although the tendency is to clean out the ditches to increase water flow, the ditches are deep and contain ample volume. The vegetation present in these ditches is providing nutrient and sediment removal and these benefits should be maintained and encouraged. Figure 10.1 shows a good example a grassed buffer between crops and a well-vegetated ditch.

Construction Site Erosion and Sedimentation Pollution Control

Nonpoint source pollution from site development, including the construction of individual new homes, may be very significant during earthmoving and construction activities. The potential for soil erosion is very high until the site is stabilized with permanent vegetative cover, and is further heightened when soils are "highly erodible" and on steep slopes. Typically, large-scale development projects receive greater attention with respect to the installation and maintenance of proper erosion and sedimentation pollution controls. However, smaller construction projects such as single family residential sites in many cases lack proper erosion and sedimentation pollution controls. In fact, at many small construction sites, no erosion and sedimentation pollution controls are implemented.

Erosion and sedimentation pollution control plans should be prepared and implemented for all construction activities in the Ball Lake watershed. The Steuben County SWCD and the

DeKalb County SWCD should require erosion and sediment control practices for all construction activities in the watershed, and they should inspect all new construction sites to ensure compliance. Site development or any earthmoving activities that lack or have inadequate erosion and sedimentation pollution controls should be immediately reported to the County SWCDs so that timely correction may ensue.

Dirt and Gravel Road Maintenance

Sediments washing from dirt and gravel roads are a significant source of nonpoint source pollution in rural areas such as the Ball Lake watershed. Traditional thinking in road maintenance has been to get water off of the roads and into streams or ditches by the quickest means possible. This results in excess sediments entering waterways and depositing in larger water bodies. Several instances of roadside erosion and sediments entering streams via damaged or inadequate drainage structures were evident in the Ball Lake watershed during watershed investigations. The dirt and gravel roads in the Ball Lake watershed should be properly maintained so that sediment does not enter waterways. Roads should be graded and the road edges well vegetated. Properly sized culverts at stream crossings and under driveways and cross streets are imperative, as well as adequate roadside drainage structures.

Some states, such as Pennsylvania, have a Dirt and Gravel Road Program. Pennsylvania's Dirt and Gravel Road Pollution Prevention Program is a water pollution abatement program that offers local municipalities special funding and technical support, to repair, manage and maintain their dirt and gravel roads in environmentally safe ways. The program is administered through County Conservation Districts and local Quality Assurance Boards. The PA State Conservation Commission and Center for Dirt and Gravel Road Studies periodically hold Environmentally Sensitive Maintenance training courses, which include modules on drainage, road maintenance techniques, erosion prevention and sediment controls, bank stabilization, roadside vegetation management, and grant procedures. The Steuben and DeKalb County SWCDs should evaluate Pennsylvania's program to determine if it could benefit the Ball Lake watershed.

Shallow concrete basins should be installed along dirt roads where shallow ditches convey sand and gravel into streams and waterways. This will allow for easy maintenance and removal of sediment from these shallow roadside ditches without having to dig out and disturb the ditch bottom.

Inlet and outlet protection should be provided for all culverts in the watershed. Specifically, the culvert at Station 2 (700 South Road) showed signs outlet scour and water traveling along the outside of the pipe. Inlet and outlet protection was not observed at any of the culverts observed in the watershed during sampling or field investigation. Although each individual culvert was not investigated, a dry culvert along County Line Road was noted to show considerable downstream scour and erosion. Therefore, all road culverts showing signs of erosion should have inlet and outlet protection.

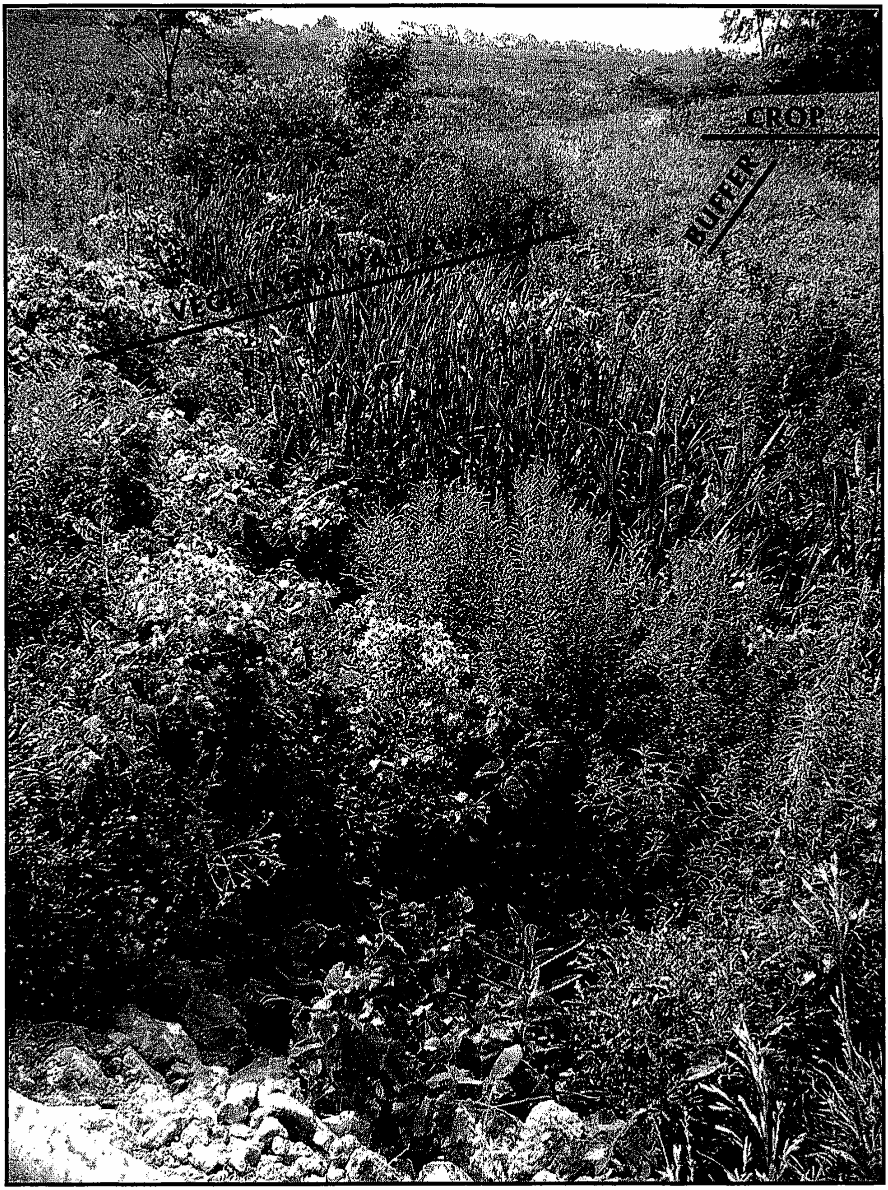

Figure 10.1 Example of good stream protection in the Ball Lake watershed, with wide vegetated buffer and well-established vegetation in the ditch

Recommendation Three - Streambank Restoration

Erosion is one of the major sources of nonpoint source pollution in watersheds. Nutrients and other pollutants adhere to eroded soil particles negatively affecting the streams and eventually the soil and pollutants are deposited in Ball Lake. Several of the streams and ditches flowing into Ball Lake have eroded streambanks and lack adequate vegetation. Eroded streambank areas were observed all along Myers Ditch, Cameron Ditch, and unnamed ditches in the watershed.

Restoration of erosion along streambanks is a successful way to significantly reduce sediment and nutrient loadings to Ball Lake for a reasonable price. By using vegetative streambank erosion measures, the erosion area is eliminated and the area acts as a vegetative buffer that can also reduce sediments and nutrients that enter the stream with stormwater runoff. During the watershed investigations, steambank erosion areas were identified along streambanks that were easily identified along roads and at stream crossings. There are a variety of methods designed to stabilize eroded streambanks and to reduce continued erosion and sedimentation. Some methods reduce the amount and velocity of water in the stream, others involve relatively high cost structural controls such as rip-rap and gabions, and still others involve relatively low-cost vegetative controls such as willow twigs, grasses, shrubs, or wetland vegetation. It is recommended that lower cost, bioengineering approaches such as willow twigging, vegetated riprap, and vegetated cribwalls be used wherever practical to stabilize the severely eroded streambank areas noted on the nonpoint source problem area map. Streambank stabilization problems have been assigned a high priority since sediment and nutrients are carried directly to the lakes from these sources.

Streambank stabilization measures need to be designed and constructed for eroding streambanks in the watershed. It is recommended that measures be implemented at sites closest to the lake initially and then the work should be expanded out into the upper reaches of the watershed. Additionally, rock check dams can be installed in the upstream ditches to reduce stormwater runoff peaks, which will reduce streambank erosion downstream.

A priority area for streambank restoration and the installation of rock check dams is along Myers ditch in the vicinity of County Line Road (NPS problem area "B"). Significant areas of high and low bank erosion was evident downstream of County Line Road. Check dams could perhaps be placed upstream of the road to reduce stormwater runoff peaks to the eroding area. An investigation of flow and grade in this area should be conducted to determine the need and possible location of rock check dams.

A second priority area for streambank restoration is along Cameron Ditch (vicinity of NPS problem areas "Q" through "U"). An investigation of flow and grade in this area should also be conducted in this area to determine the need and possible location of rock check dams.

Recommendation Four - Wetland Creation

Wetlands are valuable for a number of reasons. In addition to many other benefits, wetland systems provide a low-cost, yet highly effective method of treating stormwater runoff from urban and agricultural areas. Stormwater runoff from such areas generally carries very high concentrations of sediments, nutrients and other pollutants when compared with undeveloped land areas. Wetland enhancement systems that are constructed in the landscape are carefully designed to meet the specific requirements for the type of stormwater runoff they will treat. Pollutants which threaten the water quality of Ball Lake would be effectively removed within these systems through settling, filtration and biological treatment processes. This treatment option provides excellent removal of pollutants when properly maintained. Other benefits of newly created and enhanced wetland systems include habitat creation, minimization of flood damage through increased flood storage, improvement of water quality, and creation of educational opportunities.

Three sites were identified as possible locations for created wetland sites. The first site is located on Myers Ditch at one of three possible locations (at the intersection of 800S (County Line Road) or upstream or downstream of the intersection of the railroad tracks). The second site is located on Cameron Ditch on the upstream side of 100E, and the third site is located on the Cameron Ditch on the upstream side of Boat Launch Road. Wetland creation projects have a high priority since the can effectively filter out sediments and nutrients from stormwater runoff and also help to improve the natural habitat. A feasibility study should be initiated to determine if these sites can be converted to constructed wetlands.

Maintenance of created wetlands is essential to ensure that the system operates properly. Sediment accumulation in the sediment forebay should be monitored yearly. Once the sediment level reaches a pre-determined level (determined during the design stage), the sediment should be removed. The frequency of sediment removal will vary, depending upon the erosion in the watershed and could range from every 3-5 years to every 10-20 years. Other maintenance items include debris and litter removal, inspection of inlet/outlet structures, and nuisance insect control. Maintenance costs may range from 3% to 5% of the construction cost of the basin (Schueler, 1987).

Recommendation Five - Invasive Species Control

Establish Watershed Invasive Species Task Force

Purple loosestrife (Lythrum salicaria) needs to be eliminated from the shores of Ball Lake before it infests the valuable wetlands of the watershed. An invasive species task force should be established to patrol the watershed for a number of potential invasive plant threats to the watershed's excellent biodiversity.

CONTROL OF PURPLE LOOSESTRIFE[8]

Since mechanical and chemical control methods have only limited success and smaller infestations are more likely to be controllable, early diagnosis is critical. Potential loosestrife habitat should be searched annually during late July and August for the plant. Early detection is the best approach! Mowing, burning, and flooding have proven largely ineffective. Mowing and flooding can actually contribute to further spread of the species by disseminating seed and cut plant stems. Do not mow because cut parts may re-root.

Practices for areas with individual plants and clusters of up to 100 plants

Younger plants (1-2 years old) can be hand-pulled. Do not pull after flowering because this will scatter seed. Older plants, especially those in fens or in deep organic soils, can be dug out. Roots of older plants can be "teased" loose with a hand cultivator. Bag and remove the plants from the site. Failure to place the removed plants in a bag could result in spreading the plant along your exit route because fragments may be dropped. Dispose of the plant by burning (preferable) or in an approved landfill. Follow-up treatments are recommended for three years after the plants are removed. Clothing, equipment and personnel should be cleaned to insure no seeds are spread on them, if seeds were present on plants.

If the above control method is not feasible in areas with relatively small infestations, spot application of glyphosate herbicides can be used as described below.

Practices for areas with clusters in excess of 100 plants (up to 4 acres in size)

Spot application of a glyphosate herbicide to individual purple loosestrife plants is the recommended treatment where hand pulling is not feasible. Glyphosate is available under the trade names Roundup® and Rodeo®, products manufactured by Monsanto. Only Rodeo is registered for use over open water. By law herbicides may only be applied according to label directions.

Glyphosate is non-selective so care should be taken not to let it come in contact with non-target species. Glyphosate application is most effective when plants have just begun flowering. Timing is crucial, because seed set can occur if plants are in mid-late flower. Where feasible, the flower heads should be cut, bagged, and removed from the site before application to prevent seed set. Roundup® should be applied by hand sprayer as a one and one-half% solution (2 oz. Roundup per gallon of clean water). Rodeo® should also be applied as a one and one-half% solution (2 oz. Rodeo per gallon clean water) with the addition of a wetting agent, as specified on the Rodeo label.

Another option is to apply glyphosate twice during the growing season. Foliage should be sprayed as described above, once when flowering has just started and a second time 2-3 weeks later. With this procedure control is likely more effective, because plants are not

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[8]Source: Vegetation Management Guidelines, Illinois Nature Preserves Commission

allowed to set seed and those missed because they were not flowering the first time are treated the second time.

Excessive application of herbicide (causing dripping from the plant) can kill desirable plants under the loosestrife. These plants, left unharmed, will be important in recolonizing the site after the loosestrife has been controlled. If the desirable plants are killed, the vigorously resprouting and growing purple loosestrife seeds present in the soil will fill the void. Since purple loosestrife is usually taller than the surrounding vegetation, application to the tops of plants alone can be very effective and limit exposure of non-target species. Complete coverage is not required to affect control.

The herbicide should be applied while backing away from treated areas to avoid walking through the wet herbicide. Equipment, clothing and personnel should be cleaned completely before entering other uninfested sensitive areas, if seeds were present in the treated area. It will be necessary to treat the same area again annually until missed plants and plants originating from the seed bank are eliminated. Relatively young populations seem to be almost eliminated in 2-3 years of consecutive treatment while older stands will require more treatment.

Fisheries Management Recommendations

The over-abundance of gizzard shad in Ball Lake present a challenge to the management of the Ball Lake fishery. When small, shad provide an excellent forage food source for game fish. However, gizzard shad can quickly outgrow the size where they are a good food source, at which time their numbers increase and the fishery becomes unbalanced. The only sure method of removing the gizzard shad to restore the fishery is to conduct a whole lake reclamation. This will kill off all of the fish so that restocking can take place. While this is relatively inexpensive, there are environmental concerns due to impacts on non-target species, water quality concerns caused by the alteration of the food web, and public health concerns related to some of the compounds that are mixed in with rotenone, the active ingredient most often used to reclaim lakes. Ultimately, the decision as to how to best manage the fishery should be conducted by IDNR, since this is a public resource.

Funding Sources

There are a number of potential sources of funding for implementing Ball Lake management alternatives. Some of the programs that provide funding can be applied for directly by the Otsego Ball Lake Association, while others are administered at the county level in direct cooperation with watershed land owners. In addition to the state and federal sources listed below, private preservation interests have already demonstrated a willingness to spend funds for preserving lands in the Ball Lake watershed.

Lake and River Enhancement Program (LARE)

The LARE program provides funding for construction activities associated with recommendations in a diagnostic study. A maximum of $300,000 may be available for activities within the Ball Lake watershed, with a requirement of 25 percent matching funds or in-kind service.

The LARE program also provides funding for Watershed Land Treatment (WLT). These grants can be applied for annually by the county Soil & Water Conservation Districts. Often the LARE WLT funds can be coordinated with federal conservation programs to offer landowners greater incentives to implement best management practices. The lake association should coordinate its restoration efforts with the county SWCDs to access some of this funding.

The LARE program accepts "pre-applications" each year for funding that will become available in July. Submission of a pre-application form is required from any lake organization interested in acquiring funding for diagnostic, engineering feasibility, design or construction projects. Organizations which are interested should complete the pre-application form and return it to the LARE office by January 31 for the year in which funding is desired.

For more information about the LARE program, contact the LARE coordinator (see Section 9) or visit the LARE Program website at
http://www.in.gov/dnr/soilcons/programs/lare.html

Nonpoint Source Pollution Management Grant

In Indiana, the IDEM administers the federal Clean Water Act Section 319 Nonpoint Source Pollution Management Grant program. This program may be used to address nonpoint source pollution such as streambank erosion in the Ball Lake watershed. A maximum of $300,000 may be available, with a requirement of 25 percent matching funds or in-kind service. Applications for the Federal Section 319 Grants are due October 1. Projects selected for funding will be able to start work July 1 in the year following the application.

The Watershed Management Section administers the Section 319 Grant Program in Indiana. For more information about Section 319 funding, please contact Laura Bieberich at (317) 233-1863 or Doug Campbell at (317) 233-8491 or visit the IDEM 319 Grant web page at
http://www.in.gov/idem/water/planbr/wsm/319main.html

Watershed Protection and Flood Prevention Program

This federal program is administered by the local county offices of the Natural Resource County Service. Relevant funding priorities for the Ball Lake watershed include watershed protection, flood prevention, erosion and sediment control, fish and wildlife habitat enhancement, wetland creation and restoration, and public recreation in small watersheds. The amount of the money available is variable, but flood control projects are fully funded with no match, while agricultural water management, recreation and fish and wildlife construction projects require a 50 percent match. Eligible project sponsors (Local or state agency, county, municipality, town or township, soil and water conservation district, flood prevention/flood control district, Indian tribe or tribal organization, or other subunit of state government)may submit formal requests for assistance to the NRCS state Conservationist in each state at any time.

For more information, contact the local NRCS representative (see Section 9) or go to http://www.epa.gov/owow/watershed/wacademy/fund/prevent.html

Conservation Reserve Program

This federal program is administered by the county offices of the Farm Services Agency and provides cost-sharing and incentive payments to farmers to establish and maintain vegetation on their properties. Much of the Ball Lake watershed contains eligible lands for this program, since the program is targeted at farm lands with a high potential of degrading water quality under normal usage and areas that might make good habitat if not farmed. These target areas include highly erodible land, riparian zones, and farmed wetlands. A 50 percent match is required for construction and planting.

For more information, contact the county Farm Services Agency office (see Section 9) or go to http://www.fsa.usda.gov/dafp/cepd/crp.htm

Wetlands Reserve Program

This federal program is administered by the local county offices of the Natural Resource County Service and provides funding to landowners for the restoration of wetlands on agricultural land. Landowners receive cost-sharing and incentive payments to restore wetlands in farmed wetlands, drained and tiled lands, riparian zones, and lands adjacent to protected wetlands. No match is required.

For more information, contact the local NRCS representative (see Section 9) or go to http://www.nrcs.usda.gov/programs/wrp/

Wildlife Habitat Incentive Program

This federal program is administered by the local county offices of the Natural Resource County Service and provides funding and technical support to landowners for the development and improvement of wildlife habitat on private lands. A 25 percent match is required.

For more information, contact the local NRCS representative (see Section 9) or go to http://www.nrcs.usda.gov/programs/whip/

North American Wetland Conservation Act Grant Program

This federal program is funded by the US Department of the Interior and administered through its local Fish and Wildlife Service offices. A North American Wetlands Conservation Act standard grant proposal is a 4-year plan of action supported by a NAWCA grant and partner funds to conserve wetlands and wetlands-dependent fish and wildlife through acquisition (including easements and land title donations), restoration and/or enhancement, with a grant request between $51,000 and $1,000,000. Small grants (up to $50,000) are administered separately. Match must be non-Federal and at least equal the grant request (referred to as a 1:1 match). Match is eligible up to 2 years prior to the year the proposal is submitted and grant and match funds are eligible after the proposal is submitted and through the project period.

The 2003 Deadlines for Standard Grants are March 7 and July 25, 2003.

For more information, contact the North American Waterfowl Management Plan Joint Venture Coordinator for Indiana at:

Barbara Pardo, Joint Venture Coordinator (barbara_pardo@fws.gov)
Paul Richert, Assistant Joint Venture Coordinator (paul_richert@fws.gov)
U.S. Fish and Wildlife Service
One Federal Drive
Fort Snelling, MN 55111-4056

or visit the following NAWCA websites:
General Info • http://northamerican.fws.gov/NAWCA/grants.htm
Small Grants Program • http://northamerican.fws.gov/NAWCA/USsmallgrants.html
Standard Grants Program • http://northamerican.fws.gov/NAWCA/USstandgrants.html

Land and Water Conservation Fund

This federal program provides funding for park, wildlife, and open space land acquisition. It is administered by the IDNR Division of Outdoor Recreation and provides matching grants to States and local governments for the acquisition and development of public outdoor recreation areas and facilities. The Land and Water Conservation Fund applicants may request amounts ranging from a minimum of $10,000 up to a maximum of $200,000. Only park and recreation boards established under Indiana law are eligible. Applications must be submitted or post-marked by June 1. In order to be eligible for these moneys, Ball Lake must be ranked by IDNR on their statewide recreation plan and the lake association must work with a local park and recreation board.

The Land and Water Conservation Fund is a reimbursing program, the project sponsor does not receive the grant funds at the time of application approval. The sponsor must have the local matching 50% of the project cost available prior to the application. The sponsoring park and recreation board is reimbursed 50% of the actual costs of the approved project. In order to receive the money reserved for the project, a billing must be submitted to your grant coordinator that enables the participants to request the federal share of the cost incurred throughout the grant term.

For more information contact:

Bob Bronson
State & Community Outdoor Recreation Planning Section
Division of Outdoor Recreation
Indiana Department of Natural Resources
402 West Washington Street, Room 271
Indianapolis, Indiana 46204-2782
(317) 232-4070

or visit the LWCF website at http://www.in.gov/dnr/outdoor/grants/lwcf.html

Public Information

Public Information Handout

A public information PowerPoint presentation was developed that describes the findings and recommendations of the Ball Lake Diagnostic Study has been developed. A copy of the PowerPoint file has been provided to the LARE office, and a printout is included in the Appendices. The Otsego Ball Lake Association and local resource agencies may be able to assist in its distribution.

Public Meeting

A public meeting was held on April 20, 2002. Approximately 15 to 20 people were present, including area residents, LARE representatives, and local county agency representatives. The findings and recommendations of this study was presented to the assembled group, followed by a presentation on *Cylindrospermopsis*.

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APPENDIX A

Glossary of Lake and Watershed Terms

Glossary of Lake and Watershed Terms

Algae: Small aquatic plants that occur as single cells, colonies, or filaments. Planktonic algae float freely in the open water. Filamentous algae form long threads and are often seen as mats on the surface in shallow areas of the lake.

Alkalinity: The capacity of a solution to neutralize strong acids. The components of alkalinity include weak bases (carbonate species, dissociated organic acids, alumino-hydroxides, borates, and silicates) and strong bases (primarily, OH-).

Anaerobic: Describes processes that occur in the absence of molecular oxygen.

Anoxia: A condition of no oxygen in the water. Often occurs near the bottom of fertile stratified lakes in the summer and under ice in late winter.

Anoxic: "Without oxygen." (see *anoxia*).

Chlorophyll a: Chlorophyll is a green pigment in algae and other green plants that is essential for the conversion of sunlight, carbon dioxide and water to sugar (photosynthesis). Sugar is then converted to starch, proteins, fats and other organic molecules. Chlorophyll a is a type of chlorophyll present in all types of algae, sometimes in direct proportion to the biomass of algae.

Epilimnion: Uppermost warmest well-mixed layer of a lake during summertime thermal stratification. The epilimnion extends from the surface to the thermocline.

Eutrophic: From Greek for well-nourished; describes a lake of high photosynthetic activity (plants and.or algae), high nutrient concentration and low transparency.

Eutrophication: The process of physical, chemical, and biological changes associated with nutrient, organic matter, silt enrichment, and sedimentation of a lake or reservoir. If the process is accelerated by man-made influences it is termed cultural eutrophication.

Hypolimnion: Lower, cooler layer of a lake during summertime thermal stratification.

Limnology: Scientific study of fresh water, especially the history, geology, biology, physics, and chemistry of lakes. Also termed freshwater ecology. A limnologist is one who studies limnology.

Mesotrophic: Describes a lake of moderate plant productivity and transparency; a trophic state between oligotrophic and eutrophic.

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adapted from: *The Lake and Reservoir Restoration Guidance Manual* (US EPA 1990)

Nutrient: An element or chemical essential to life, such as carbon, oxygen, nitrogen, and phosphorus.

Oligotrophic: "Poorly nourished," from the Greek. Describes a lake of low plant productivity and high transparency.

pH: A measure of the concentration of hydrogen ions of a substance, which ranges from very acid (pH = 1) to very alkaline (pH = 14). pH 7 is neutral and most lake waters range between 6 and 9. pH values less than 6 are considered acidic, and most life forms can not survive at pH of 4.0 or lower.

Phytoplankton: Microscopic algae and microbes that float freely in open water of lakes and oceans.

Secchi depth: A measure of transparency of water obtained by lowering a black and white, or all white, disk (Secchi disk, 20 cm in diameter) into water until it is no longer visible. Measured in units of meters or feet.

Sediment: Bottom material in a lake that has been deposited after the formation of a lake basin. It originates from remains of aquatic organisms, chemical precipitation of dissolved minerals, and erosion of surrounding lands.

Thermal stratification: Layering of water caused by temperature-created differences in water density. Thermal stratification is typical of most deep lakes during summer.

Thermocline: A horizontal plane across a lake at the depth of the most rapid vertical change in temperature and density in a stratified lake.

Trophic state: The degree of eutrophication of a lake. Transparency, chlorophyll a levels, phosphorus concentrations, amount of macrophytes, and quantity of dissolved oxygen in the hypolimnion can be used to assess state.

Water column: Water in the lake between the interface with the atmosphere at the surface and the interface with the sediment layer at the bottom. Idea derives from vertical series of measurements (oxygen, temperature, phosphorus) used to characterize lake water.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

APPENDIX B

QHEI Field/Calculation Sheets

OhioEPA Qualitative Habitat Evaluation Index Field Sheet QHEI Score: 42

/er Code:________RM: _____ Stream Cameron Ditch - Station 3

ite 8/15/01 Location 100 East Crossing

orers Initials: MM/ASA Comments

SUBSTRATE (Check *ONLY* Two Substrate *TYPE BOXES; Estimate % present*);

'PE	POOL RIFFLE		POOL RIFFLE	SUBSTRATE ORIGIN Check ONE (OR 2 & AVERAGE)		SUBSTRATE QUALITY Check ONE (OR 2 & AVERAGE)
☐-BLDR/SLBS[10]		☒ ☒-GRAVEL [7]	75 75			
☐-BOULDER [9]		☐ ☐-SAND [6]		☐ -LIMESTONE [1]	SILT:	☐ -SILT HEAVY [-2]
☐-COBBLE [8]		☐ ☐-BEDROCK[5]		☒ -TILLS [1]		☒ -SILT MODERATE [-1]
☐-HARDPAN [4]		☐ ☐-DETRITUS[3]		☐ -WETLANDS[0]		☐ -SILT NORMAL [0]
☐-MUCK [2]		☐ ☐-ARTIFICIAL[0]		☐ -HARDPAN [0]		☐ -SILT FREE [1]
☒-SILT [2]	25 25			☐ -SANDSTONE [0]	EMBEDDED	☐ -EXTENSIVE [-2]
				☐ -RIP/RAP [0]	NESS:	☒ -MODERATE [-1]
				☐ -LACUSTRINE [0]		☐ -NORMAL [0]
				☐ -SHALE [-1]		☐ -NONE [1]
				☐-COAL FINES [-2]		

'TE: (*Ignore sludge originating from point-sources; ire on natural substrates*) ☐-5 or More [2]

JMBER OF SUBSTRATE TYPES: ☒-4 or Less [0]

)MMENTS____________

Substrate: 8 (Max 20)

INSTREAM COVER (see back for instructions for additional cover scoring method)

TYPE: (Check *All* That Apply)

- ___UNDERCUT BANKS [1]
- ___OVERHANGING VEGETATION [1]
- ___SHALLOWS (IN SLOW WATER) [1]
- ___ROOTMATS [1]
- ☐ ___POOLS> 70 cm [2]
- ☒ ___ROOTWADS [1]
- ☐ ___BOULDERS [1]
- ☐___OXBOWS, BACKWATERS [1]
- ☐___AQUATIC MACROPHYTES [1]
- ☒___LOGS OR WOODY DEBRIS [1]

COMMENTS:____________

AMOUNT: (Check *ONLY* One or check 2 and *AVERAGE*)

- ☐ - EXTENSIVE > 75% [11]
- ☐ - MODERATE 25-75% [7]
- ☐ - SPARSE 5-25% [3]
- ☒ - NEARLY ABSENT < 5%[1]

Cover: 6 (Max 20)

CHANNEL MORPHOLOGY: (Check *ONLY* One PER Category OR check 2 and *AVERAGE*)

'NUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY	MODIFICATIONS/OTHER	
-HIGH [4]	☐-EXCELLENT [7]	☐-NONE [6]	☐-HIGH [3]	☐-SNAGGING	☐-IMPOUND.
-MODERATE [3]	☐-GOOD [5]	☐-RECOVERED [4]	☒-MODERATE [2]	☐-RELOCATION	☐-ISLANDS
-LOW [2]	☐-FAIR [3]	☒-RECOVERING [3]	☐-LOW [1]	☐-CANOPY REMOVAL	☐-LEVEED
-NONE [1]	☒-POOR [1]	☐-RECENT OR NO RECOVERY [1]		☐-DREDGING	☐-BANK SHAPING
				☐-ONE SIDE CHANNEL MODIFICATIONS	

Channel: 8 (Max 20)

)MMENTS: Channelization resulting from road bridge installation

RIPARIAN ZONE AND BANK EROSION-(check ONE box per bank or check 2 and AVERAGE per bank) ★River Right Looking Downstream★

RIPARIAN WIDTH L R (Per Bank)	FLOOD PLAIN QUALITY (*PAST 100 Meter RIPARIAN*) L R (Most Predominant Per Bank)	L R	BANK EROSION L R (Per Bank)
☐ ☐-WIDE > 50m [4]	☐ ☒-FOREST, SWAMP [3]	☐ ☐-CONSERVATION TILLAGE [1]	☒ ☒-NONE/LITTLE [3]
☐ ☐-MODERATE 10-50m [3]	☒ ☐-SHRUB OR OLD FIELD [2]	☐ ☐-URBAN OR INDUSTRIAL [0]	☐ ☐-MODERATE [2]
☒ ☒-NARROW 5-10m [2]	☐ ☐-RESIDENTIAL, PARK, NEW FIELD [1]	☐ ☐-OPEN PASTURE, ROWCROP [0]	☐ ☐-HEAVY/SEVERE [1]
☐ ☐-VERY NARROW < 5m [1]	☐ ☐-FENCED PASTURE [1]	☐ ☐-MINING/CONSTRUCTION [0]	
☐ ☐-NONE [0]			

Riparian: 10 (Max 10)

OMMENTS:____________

POOL/GLIDE AND RIFFLE/RUN QUALITY

MAX. DEPTH (Check 1 ONLY!)	MORPHOLOGY (Check 1 or 2 & AVERAGE)	CURRENT VELOCITY [POOLS & RIFFLES!] (Check *All* That Apply)	
- >1m [6]	☐-POOL WIDTH > RIFFLE WIDTH [2]	☐-EDDIES [1]	☐-TORRENTIAL [-1]
- 0.7-1m [4]	☒-POOL WIDTH = RIFFLE WIDTH [1]	☐-FAST [1]	☒-INTERSTITIAL [-1]
- 0.4-0.7m [2]	☐-POOL WIDTH < RIFFLE W. [0]	☐-MODERATE [1]	☒-INTERMITTENT [-2]
- 0.2-0.4m [1]		☒-SLOW [1]	
- < 0.2m [POOL=0]			

COMMENTS:____________

Pool/Current: 1 (Max 12)

CHECK ONE OR CHECK 2 AND AVERAGE

RIFFLE DEPTH	RUN DEPTH	RIFFLE/RUN SUBSTRATE	RIFFLE/RUN EMBEDDEDNESS
- *Best Areas >10 cm [2]	☐ - MAX > 50 [2]	☐-STABLE (e.g.,Cobble, Boulder) [2]	☐ - NONE [2]
- Best Areas 5-10 cm [1]	☒ - MAX < 50 [1]	☐-MOD. STABLE (e.g.,Large Gravel) [1]	☐ - LOW [1]
- Best Areas < 5 cm [RIFFLE=0]		☒-UNSTABLE (Fine Gravel,Sand) [0]	☒ - MODERATE [0]
			☐ - EXTENSIVE [-1]

OMMENTS:____________ ☐ - NO RIFFLE [Metric=0]

Riffle/Run: 3 (Max 8)

Gradient: 6 (Max 10)

GRADIENT (ft/mi): 41 **DRAINAGE AREA (sq.mi.):** 0.2

%POOL: 10 %GLIDE: 75

%RIFFLE: 10 %RUN: 5

*Best areas must be large enough to support a population of riffle-obligate fish species.

OhioEPA Qualitative Habitat Evaluation Index Field Sheet QHEI Score: 54

River Code: ________ RM: ____ Stream Myers Ditch - Station 4
Date 8/15/01 Location south (upstream) of 800 South
Scorers Initials: MM/ASA Comments ____________

1] SUBSTRATE (Check *ONLY* Two Substrate *TYPE BOXES; Estimate % present*);

TYPE	POOL	RIFFLE	TYPE	POOL	RIFFLE
☐ ☐-BLDR/SLBS[10]			☒ ☒-GRAVEL [7]	60	60
☐ ☐-BOULDER [9]			☐ ☐-SAND [6]		
☒ ☒-COBBLE [8]	40	40	☐ ☐-BEDROCK[5]		
☐ ☐-HARDPAN [4]			☐ ☐-DETRITUS[3]		
☐ ☐-MUCK [2]			☐ ☐-ARTIFICIAL[0]		
☐ ☐-SILT [2]					

NOTE: (Ignore sludge originating from point-sources; score on natural substrates)
NUMBER OF SUBSTRATE TYPES: ☐-5 or More [2] ☒-4 or Less [0]
COMMENTS ____________

SUBSTRATE ORIGIN Check ONE (OR 2 & AVERAGE)
☐ -LIMESTONE [1]
☒ -TILLS [1]
☐ -WETLANDS[0]
☐ -HARDPAN [0]
☐ -SANDSTONE [0]
☐ -RIP/RAP [0]
☐ -LACUSTRINE [0]
☐ -SHALE [-1]
☐ -COAL FINES [-2]

SUBSTRATE QUALITY Check ONE (OR 2 & AVERAGE)
SILT: ☐ -*SILT HEAVY [-2]* ☒ -SILT MODERATE [-1] ☐ -SILT NORMAL [0] ☐ -SILT FREE [1]
EMBEDDEDNESS: ☐ -EXTENSIVE [-2] ☐ -MODERATE [-1] ☒ -NORMAL [0] ☐ -NONE [1]

Substrate 15 Max 20

2] INSTREAM COVER (see back for instructions for additional cover scoring method)
TYPE: (Check *All* That Apply)
☒ __UNDERCUT BANKS [1] ☐ __POOLS> 70 cm [2] ☐ __OXBOWS, BACKWATERS [1]
☒ __OVERHANGING VEGETATION [1] ☒ __ROOTWADS [1] ☐ __AQUATIC MACROPHYTES [1]
☒ __SHALLOWS (IN SLOW WATER) [1] ☒ __BOULDERS [1] ☒ __LOGS OR WOODY DEBRIS [1]
☒ __ROOTMATS [1] COMMENTS: ____________

AMOUNT: (Check *ONLY* One or check 2 and *AVERAGE*)
☐ - EXTENSIVE > 75% [11]
☐ - MODERATE 25-75% [7]
☐ - SPARSE 5-25% [3]
☒ - NEARLY ABSENT < 5%[1]

Cover 8 Max 20

3] CHANNEL MORPHOLOGY: (Check *ONLY* One PER Category OR check 2 and *AVERAGE*)

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY
☐-HIGH[4]	☐-EXCELLENT[7]	☐-NONE[6]	☐-HIGH[3]
☐-MODERATE[3]	☐-GOOD[5]	☐-RECOVERED[4]	☐-MODERATE[2]
☐-LOW[2]	☒-FAIR[3]	☒-RECOVERING[3]	☒-LOW[1]
☒-NONE[1]	☐-POOR[1]	☐-RECENT OR NO RECOVERY[1]	

MODIFICATIONS/OTHER
☐-SNAGGING ☐-IMPOUND.
☐-RELOCATION ☐-ISLANDS
☐-CANOPY REMOVAL ☐-LEVEED
☐-DREDGING ☐-BANK SHAPING
☐-ONE SIDE CHANNEL MODIFICATIONS

Channel 8 Max 20

COMMENTS: Channelization resulting from road culvert installation

4]. RIPARIAN ZONE AND BANK EROSION-(check ONE box per bank or check 2 and AVERAGE per bank) ★River Right Looking Downstream★

RIPARIAN WIDTH — L R (Per Bank)
☐ ☒ -WIDE >50m[4]
☒ ☐-MODERATE 10-50m[3]
☐ ☐-NARROW 5-10m[2]
☐ ☐-VERY NARROW <5m[1]
☐ ☐-NONE[0]

FLOOD PLAIN QUALITY (*PAST 100 Meter RIPARIAN*) — L R (Most Predominant Per Bank)
☒ ☒-FOREST, SWAMP [3]
☐ ☐-SHRUB OR OLD FIELD [2]
☒ ☐-RESIDENTIAL, PARK, NEW FIELD [1]
☐ ☐-FENCED PASTURE [1]
☐ ☐-CONSERVATION TILLAGE [1]
☐ ☐-URBAN OR INDUSTRIAL [0]
☐ ☐-OPEN PASTURE, ROWCROP [0]
☐ ☐-MINING/CONSTRUCTION [0]

BANK EROSION — L R (Per Bank)
☐ ☐-NONE/LITTLE [3]
☐ ☐-MODERATE [2]
☒ ☒-HEAVY/SEVERE[1]

Riparian 10 Max 10

COMMENTS: ____________

5.]POOL/GLIDE AND RIFFLE/RUN QUALITY

MAX. DEPTH (Check 1 ONLY!)
☐ - >1m [6]
☐-0.7-1m[4]
☐-0.4-0.7m[2]
☒-0.2-0.4m[1]
☐ - < 0.2m [POOL=0]

MORPHOLOGY (Check 1 or 2 & AVERAGE)
☒-POOL WIDTH > RIFFLE WIDTH [2]
☐-POOL WIDTH = RIFFLE WIDTH [1]
☐-POOL WIDTH < RIFFLE W. [0]

CURRENT VELOCITY [POOLS & RIFFLES!] (Check *All* That Apply)
☐-EDDIES[1] ☐-TORRENTIAL[-1]
☐-FAST[1] ☐-INTERSTITIAL[-1]
☒-MODERATE[1] ☐-INTERMITTENT[-2]
☐-SLOW[1]

COMMENTS: ____________

Pool/Current 4 Max 12

CHECK ONE OR CHECK 2 AND AVERAGE

RIFFLE DEPTH
☐ - *Best Areas >10 cm [2]
☐ - Best Areas 5-10 cm[1]
☒ - Best Areas < 5 cm [RIFFLE=0]

RUN DEPTH
☐ - MAX > 50 [2]
☒ - MAX < 50[1]

RIFFLE/RUN SUBSTRATE
☐-STABLE (e.g.,Cobble, Boulder) [2]
☒-MOD. STABLE (e.g.,Large Gravel) [1]
☐-UNSTABLE (Fine Gravel,Sand) [0]

RIFFLE/RUN EMBEDDEDNESS
☐ - NONE [2]
☒ - LOW [1]
☒ - MODERATE [0]
☐ - EXTENSIVE [-1]

Riffle/Run 3 Max 8

COMMENTS: ____________ ☐ - NO RIFFLE [Metric=0]

Gradient 6 Max 10

6] GRADIENT (ft/mi): 6 **DRAINAGE AREA (sq.mi.):** 0.4

%POOL: 40 %GLIDE: ____
%RIFFLE: 50 %RUN: 10

*Best areas must be large enough to support a population of riffle-obligate fish species.

APPENDIX C

PowerPoint Presentation Summary

Ball Lake Diagnostic Study

Otsego Ball Lake Association

IDNR Lake & River Enhancement Program

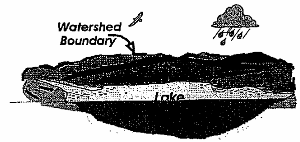
Ball Lake Diagnostic Study

Purpose

- *Describe conditions and trends in the lake*
- *Describe condition and trends in the watershed*
- *Identify potential nonpoint source water quality problems*
- *Develop a plan for future work to address identified water quality issues*

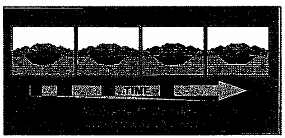
Watershed

All land that drains to a lake



Eutrophication

Natural aging process of a waterbody

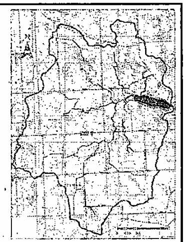


Ball Lake Watershed

7,609 acres

DeKalb County
Smithfield
Franklin

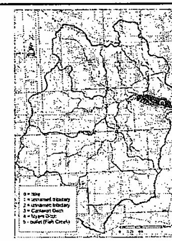
Steuben County
Steuben
Otsego



Sampling Stations & Subwatersheds

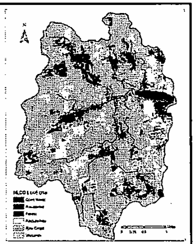
Subwatershed Areas

Station 1 - 46.7 ac
Station 2 - 84.8 ac
Station 3 - 112.4 ac
Station 4 - 278.2 ac



Land Use

Residential	***0.2 %***
Forest	
Deciduous	***15.1 %***
Evergreen/mixed	***0.1 %***
Agricultural Lands	
Pasture/Hay	***14.2 %***
Row Crops	***65.5 %***
Wetlands	
Woody	***2.4 %***
Emergent	***0.8 %***
Open Water	

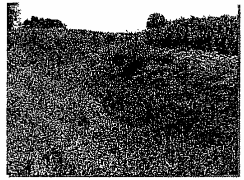


Watershed Characteristics

Watershed Characteristics

Watershed Characteristics

Watershed Characteristics

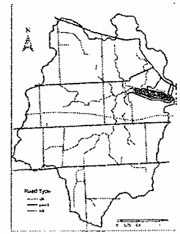


Road Cover

11.5 miles of dirt & gravel roads

13.5 miles of paved roads

3.4 miles of railroad

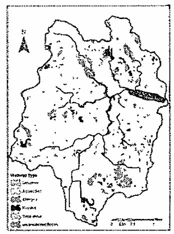


Watershed Characteristics

Wetlands

225 NWI wetlands covering 628 acres

17 miles of streams and ditches



Watershed Characteristics

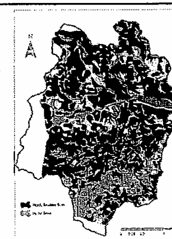
Watershed Characteristics

Watershed Characteristics

Highly Erodible & Hydric Soils

58 % of watershed has HEL soils

25 % of watershed has hydric soils



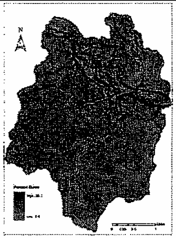
Percent Slope

130 ft difference in elevation in watershed

84 % of watershed has slopes of 0 - 5 %

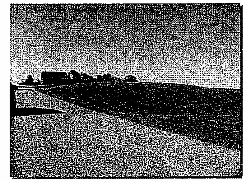
12 % of watershed has slopes of 5 - 10 %

Steep slopes near waterways

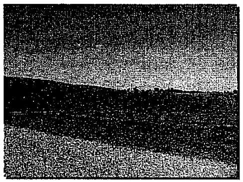


Watershed Characteristics

Watershed Characteristics



Watershed Characteristics



Watershed Characteristics

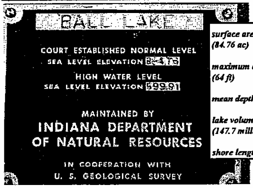
Watershed Characteristics

Watershed Characteristics

Welcome to Ball Lake

Ball Lake Public Access Site

Ball Lake Characteristics



surface area: 343,028 m2 (84.76 ac)

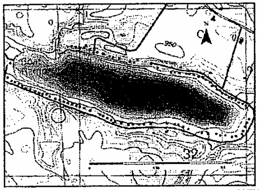
maximum depth: 19.5 m (64 ft)

mean depth: 12.2 m (40 ft)

lake volume: 4,181,820 m3 (147.7 million ft3)

shore length: 3,259 meters

Bathymetric Map of Ball Lake



Ball Lake Water Quality

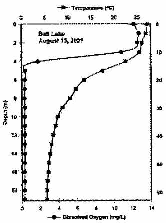
Parameter	Epilimnion (1.5 m)	Hypolimnion (16 m)
pH (s.u.)	8.7	7.4
Turbidity (NTU)	5.57	6.63
Conductivity (µmhos)	308	416
Total Phosphorus (mg/l)	0.016	0.126
Soluble Phosphorus (mg/l)	0.001	0.009
Total Kjheldahl Nitrogen (mg/l)	0.43	1.32
Nitrate/Nitrite (mg/l)	0.45	0.54
Ammonia (mg/l)	0.15	0.49
Chlorophyll a (µg/L)	15.3	
Transparency (m)	1.1	

Dissolved Oxygen & Temperature

Dissolved Oxygen Requirements:

Warm water fish
5.0 mg/L

Cold water fish
6.5 mg/L

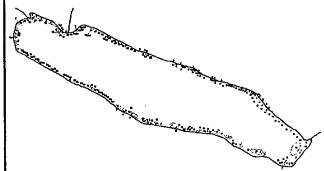


Ball Lake Water Quality

Trophic Indices

- **IDEM Eutrophy Index: 55**
  - Eutrophic
- **Carlson's Trophic State Index**
  - Total phosphorus: 44.2
    - Mesotrophic
  - Chlorophyll a: 57.3
    - Eutrophic
  - Transparency: 58.6
    - Eutrophic

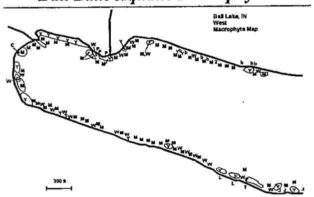
Ball Lake Aquatic Macrophytes



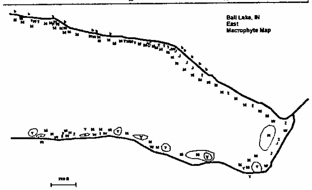
Ball Lake Aquatic Macrophytes

Scientific Name	Common Name
Scirpus americanus	American bulrush
Ceratophyllum demersum	Coontail
Najas sp. (flexilis ?)	Bushy pondweed (Slender water nymph)
Lythrum salicaria	Purple loosestrife
Myriophyllum spicatum	Eurasian watermilfoil
Pontederia cordata	Pickerelweed
Typha	Cattail
Nymphaea tuberose	White water lily
Nuphar advena	Yellow water lily
Potamogeton pulcher	Spotted pondweed
Stuckenia pectinata (P. pectinatus)	Sago pondweed

Ball Lake Aquatic Macrophytes



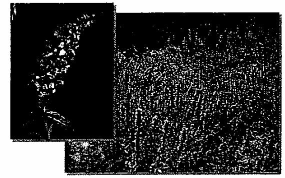
Ball Lake Aquatic Macrophytes



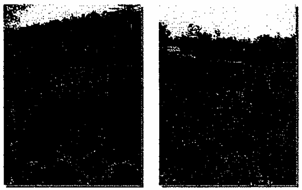
Eurasian watermilfoil

Eurasian watermilfoil

Purple Loosestrife



Purple Loosestrife



Ball Lake Fisheries

Management Activities

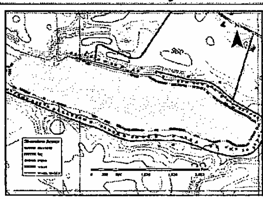
- ***1968***
  - ***Reclamation to eliminate "rough" fish***
  - ***Restocked with smallmouth bass, rock bass, rainbow trout***
- ***1983***
  - ***Gizzard shad in lake (appeared sometime after 1978)***
  - ***Trout stocking discontinued due to low survival rate***
- ***1985***
  - ***Annual tiger muskie stocking program begins***

Ball Lake Fisheries

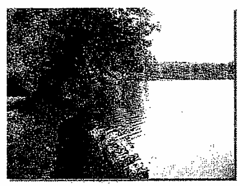
Quality of Fishery

- ***Ball Lake fishery is marginal due to overabundance of gizzard shad***
- ***Offers good opportunity to catch medium size largemouth bass and panfish***
- ***Chances of catching a tiger muskie are low***
- ***May - September 2001***
  - ***3,429 hours of fishing***
  - ***964 largemouth bass, 10 muskie and 7 tiger muskie caught and released***

Shoreline Condition of Ball Lake



Shoreline Condition of Ball Lake



Shoreline Condition of Ball Lake

Tributary Water Quality - wet

Parameter	Station 1	Station 2	Station 3	Station 4	Station 5
pH (s.u.)	7.8	8.0	7.9	7.3	
Turbidity (NTU)	4.0	5.6	24.9	22.5	
Conductivity (µmhos)	91.8	447.0	404.0		
Total Phosphorus (mg/l)	0.053	0.057	0.158	0.240	0.030
Soluble Phosphorus (mg/l)	0.066	0.004	0.066	0.146	0.038
TK Nitrogen (mg/l)	0.36	0.45	0.46	0.77	0.31
Nitrate/Nitrite (mg/l)	0.22	0.20	0.58	0.16	0.19
Fecal coliform (#/100 mL)	141	89	416	570	56
Dissolved oxygen (mg/L)	9.4	9.8	9.8	9.4	8.6
Temperature (°C)	17.0	20.0	16.0	16.0	20.0

Tributary Water Quality - dry

Parameter	Station 1	Station 2	Station 3	Station 4	Station 5
pH (s.u.)	8.1	7.9	7.8	8.2	8.7
Turbidity (NTU)	5.2	2.8	10.9	11.0	5.2
Conductivity (µmhos)	554.0	425.0	577.0	770.0	313.0
Total Phosphorus (mg/l)	0.060	0.056	0.066	0.203	0.021
Soluble Phosphorus (mg/l)	0.005	0.002	0.005	0.028	0.001
TK Nitrogen (mg/l)	0.56	0.96	0.46	0.63	1.20
Nitrate/Nitrite (mg/l)	0.20	0.01	0.65	0.95	0.43
Ammonia (mg/l)	0.12	0.11	0.10	0.10	0.10
Fecal coliform (#/100 mL)	80	171	46	30	4
Dissolved oxygen (mg/L)	8.9	6.8	3.7	7.8	10.6
Temperature (°C)	13.8	18.3	16.3	16.3	25.3

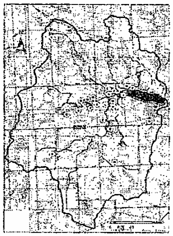
Tributary Water Quality

Macroinvertebrate & Habitat Assessment

The two main tributaries to Ball Lake, Cameron Ditch and Myers Ditch, had slight to moderate impairment based upon macroinvertebrate and habitat quality surveys.

Nonpoint Source Problem Areas

Streambank erosion was THE major nonpoint source pollution problem in the Ball Lake watershed



Nonpoint Source Problem Areas

Nonpoint Source Problem Areas

Nonpoint Source Problem Areas

Nonpoint Source Problem Areas

Nonpoint Source Problem Areas

Nonpoint Source Problem Areas

Stormwater Runoff

Base flow in Cameron Ditch

Stormwater Runoff

Spring runoff in Cameron Ditch

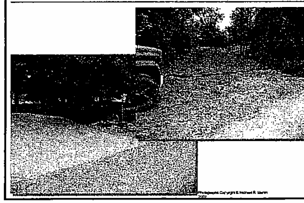
Stormwater Runoff

Base flow in Cameron Ditch

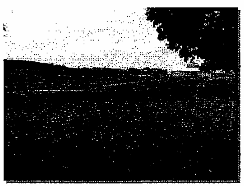
Stormwater Runoff

Spring runoff in Cameron Ditch

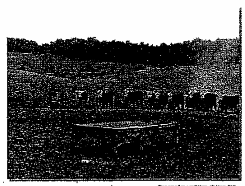
Nonpoint Source Problem Areas



Nonpoint Source Problem Areas



Nonpoint Source Problem Areas



Ball Lake Diagnostic Study

Management Recommendations

In-Lake Management Recommendations

Recommendation One - Maintain/Improve on Naturalized Shoreline

- *Maintain natural character of Ball Lake Shoreline by minimizing bulkheads*
- *Use bioengineered techniques where needed for shoreline stabilization*
- *Encourage the use of vegetated buffer strips at lake shore, using low-growing native grasses and shrubs*
- *Allow native aquatic vegetation to grow in shallow waters along the shore*

In-Lake Management Recommendations

Recommendation Two - Control of Invasive Plants

- *Remove purple loosestrife where it is growing along lake shore*
- *Use benthic mats to create boat lanes if Eurasian watermilfoil densities interfer with access to lake*
- *Create & post educational signs at public access to minimize spread of Eurasian watermilfoil to other waterbodies in the area*

In-Lake Management Recommendations

Recommendation Three - Hypolimnetic Oxygenation

- *Initiate feasibility study for adding oxygen to bottom waters of Ball Lake*
- *Preference should be given to LOx technologies due to low initial and operating costs, quietness and efficiency of operation*
- *Benefits to lake would be reduced/eliminated internal phosphorus loading and a restoration of habitat for a cold water fishery*

Watershed Management Recommendations

Recommendation One - Pesticide/Herbicide Screening in Streams

- *Investigate the source of hydrocarbon odor in streams by sampling throughout the watershed*
- *Run pesticide & herbicide screening on tributary water and sediment samples*

Watershed Management Recommendations

Recommendation Two - Land Stewardship - Ag Practices

- *Maintain CRP enrollment, encourage re-enrollment*
- *Increase use of buffers along waterways and at tile drain inlets*
- *Maintain vegetation in ditches*

Watershed Management Recommendations

Watershed Management Recommendations

Recommendation Two - Land Stewardship - Erosion & Sediment Control on Construction Sites

- *Require Erosion and Sediment Control plans for ALL construction activities in watershed*
- *Inspect construction to ensure E & S plan is implemented*

Watershed Management Recommendations

Recommendation Two - Land Stewardship - Dirt & Gravel Road Maintenance

- *Evaluate PA Dirt & Gravel Road Pollution Prevention Program for possible implementation in watershed*
- *Install shallow concrete basins in shallow roadside ditches to aid in maintenance and minimize need for digging out*
- *Install inlet and outlet protection at all culverts*

Watershed Management Recommendations

Recommendation Three - Streambank Restoration

- *Design bioengineered and structural BMPs for eroding streambanks, starting with areas closest to lake*
- *Install rock check dams in ditches to reduce stormwater runoff peaks, which will reduce erosion downstream*

Watershed Management Recommendations

Recommendation Four - Wetland Creation

- *Initiate feasibility study to evaluate sites for the construction of three wetlands at the following locations:*
  - *Myers Ditch – three potential sites near County Line Road and R/R tracks*
  - *Cameron Ditch upstream of 100E*
  - *Cameron Ditch upstream of Boat Launch Access Road*

Watershed Management Recommendations

Recommendation Five - Invasive Species Control

- *Establish county Invasive Species Task Force*
- *Patrol watershed at least annually for invasive plant species, particularly purple loosestrife*
- *Eradicate purple loosestrife & others if found*

Ball Lake Management Plan

Approximate Installation Costs

- ***Hypolimnetic Aeration or Oxygenation***
  - ***$200,000 - $750,000***
- ***Streambank Stabilization***
  - ***$20 - $75 per linear foot***
- ***Created Wetlands***
  - ***$50,000 - $125,000 per acre***

Ball Lake Diagnostic Study

The beginning . . .